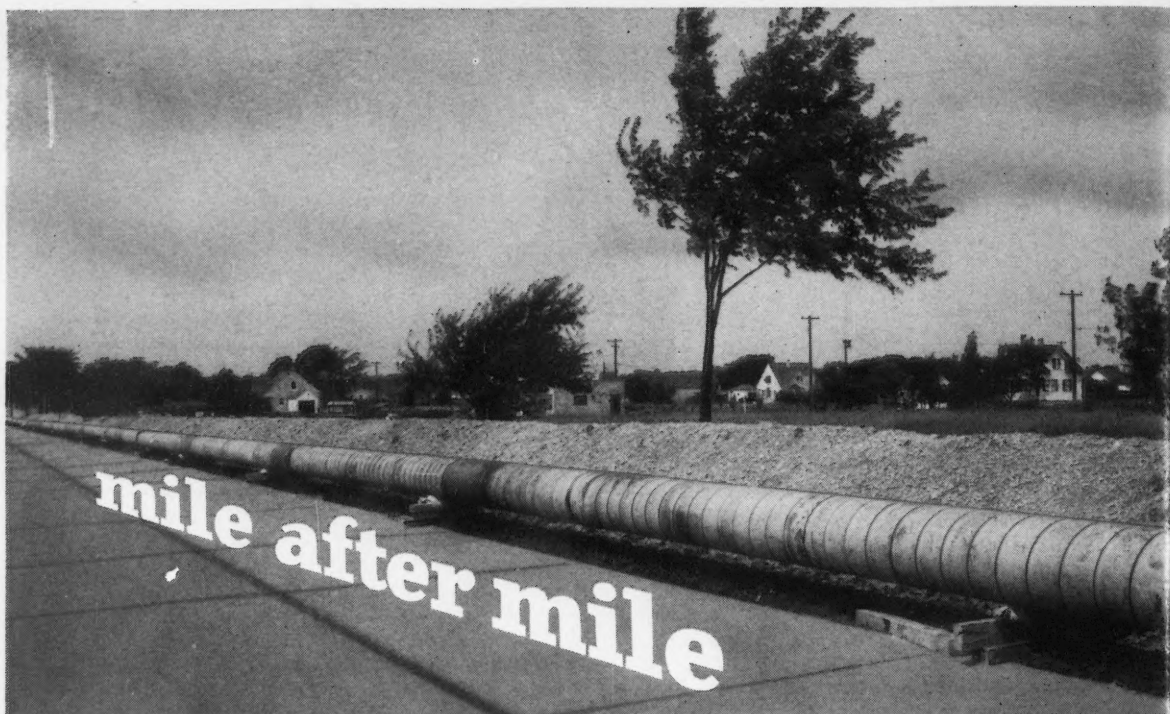


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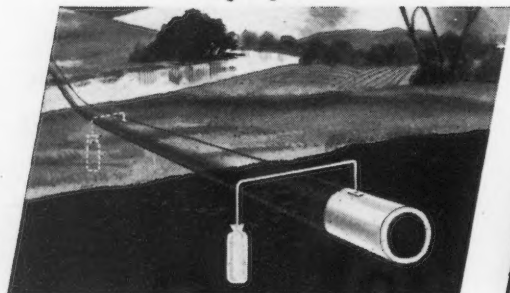
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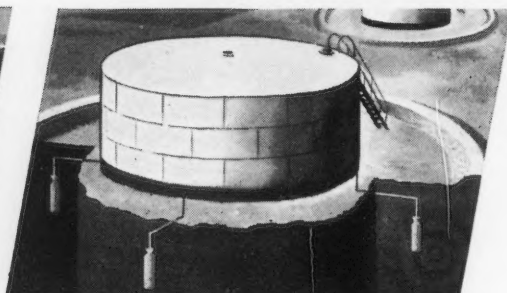
Dowell Magnesium Anodes Cut Corrosion Costs

on pipelines



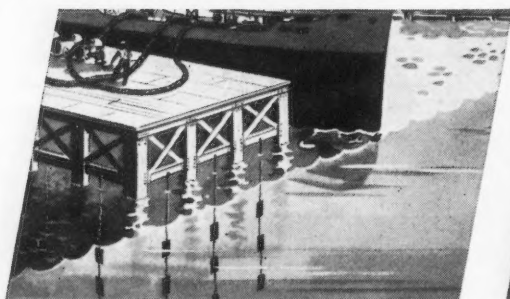
Thousands of miles of buried pipelines are being protected against corrosion at low cost by Dowell magnesium anodes. Such galvanic protection is proving equally effective on coated, wrapped and bare lines.

on tank bottoms



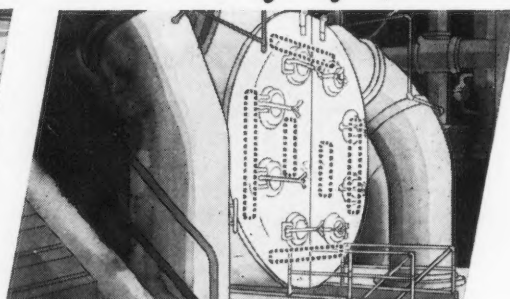
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devoted entirely to
CORROSION
research and control

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Vol. 7

JUNE, 1951

No. 6



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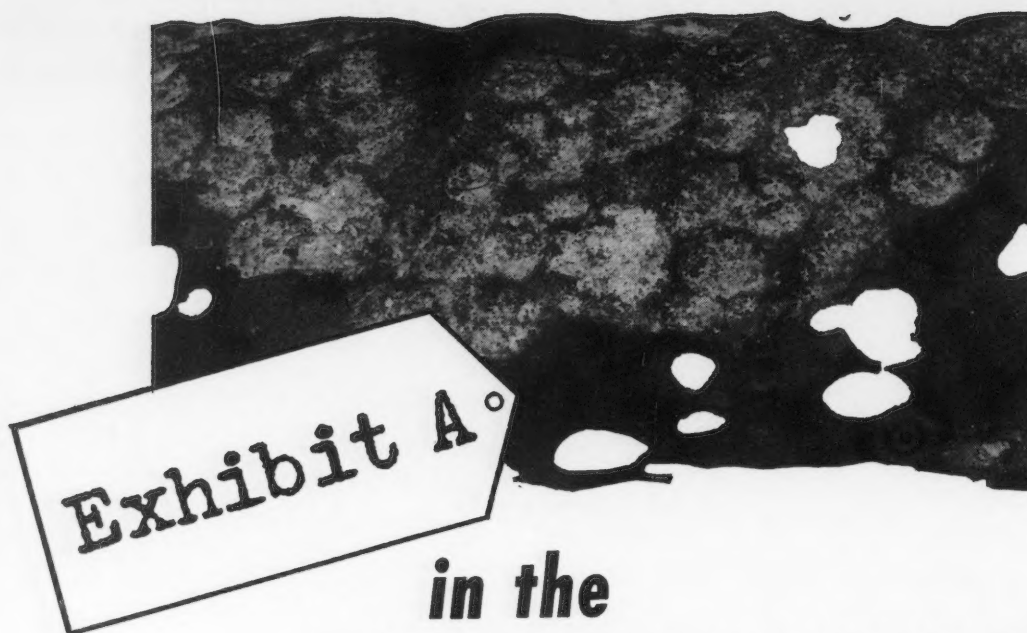
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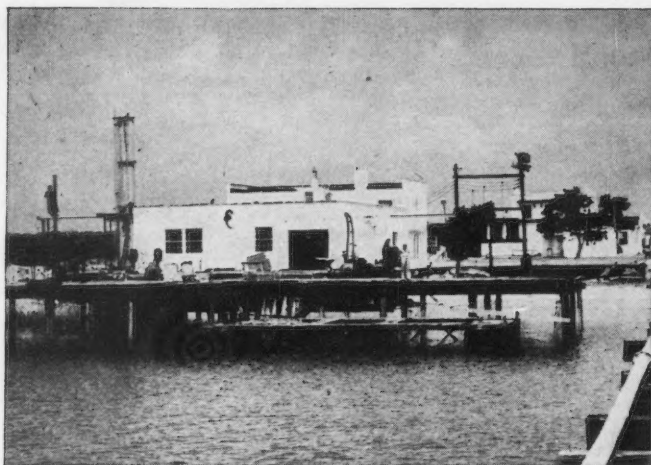
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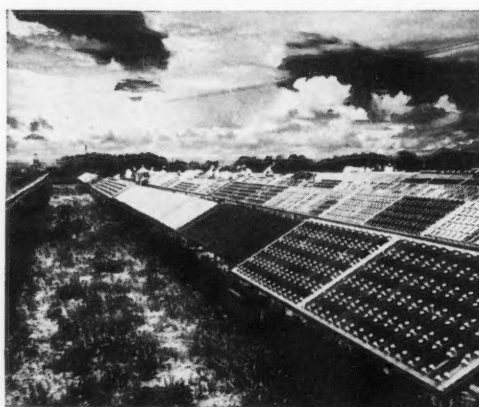
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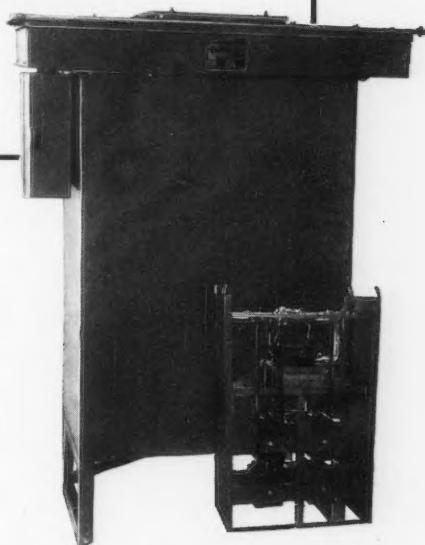
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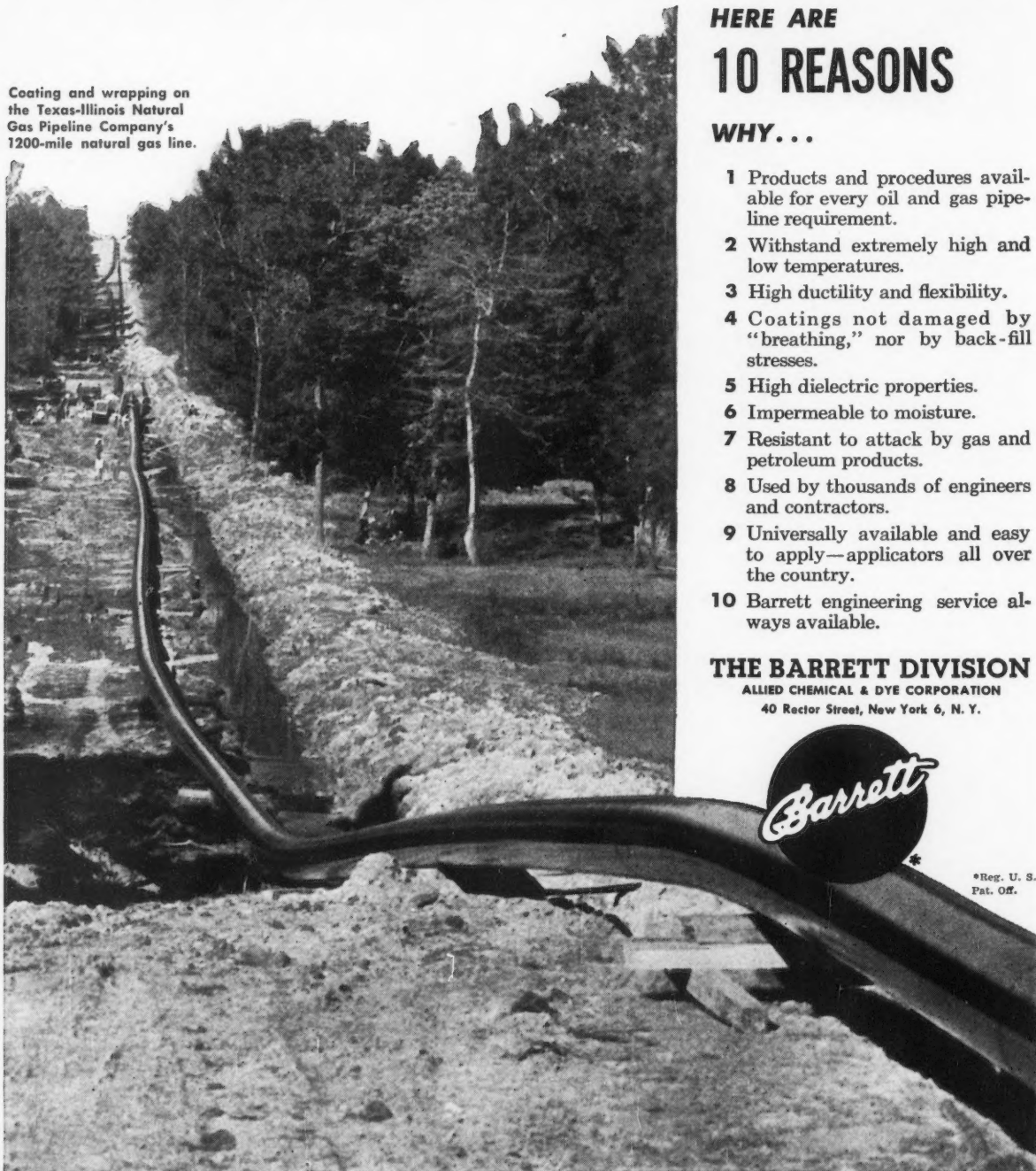
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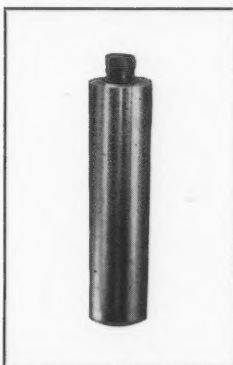
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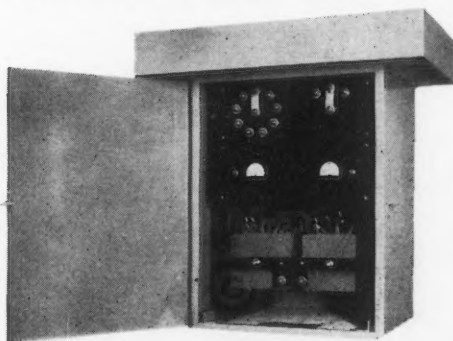


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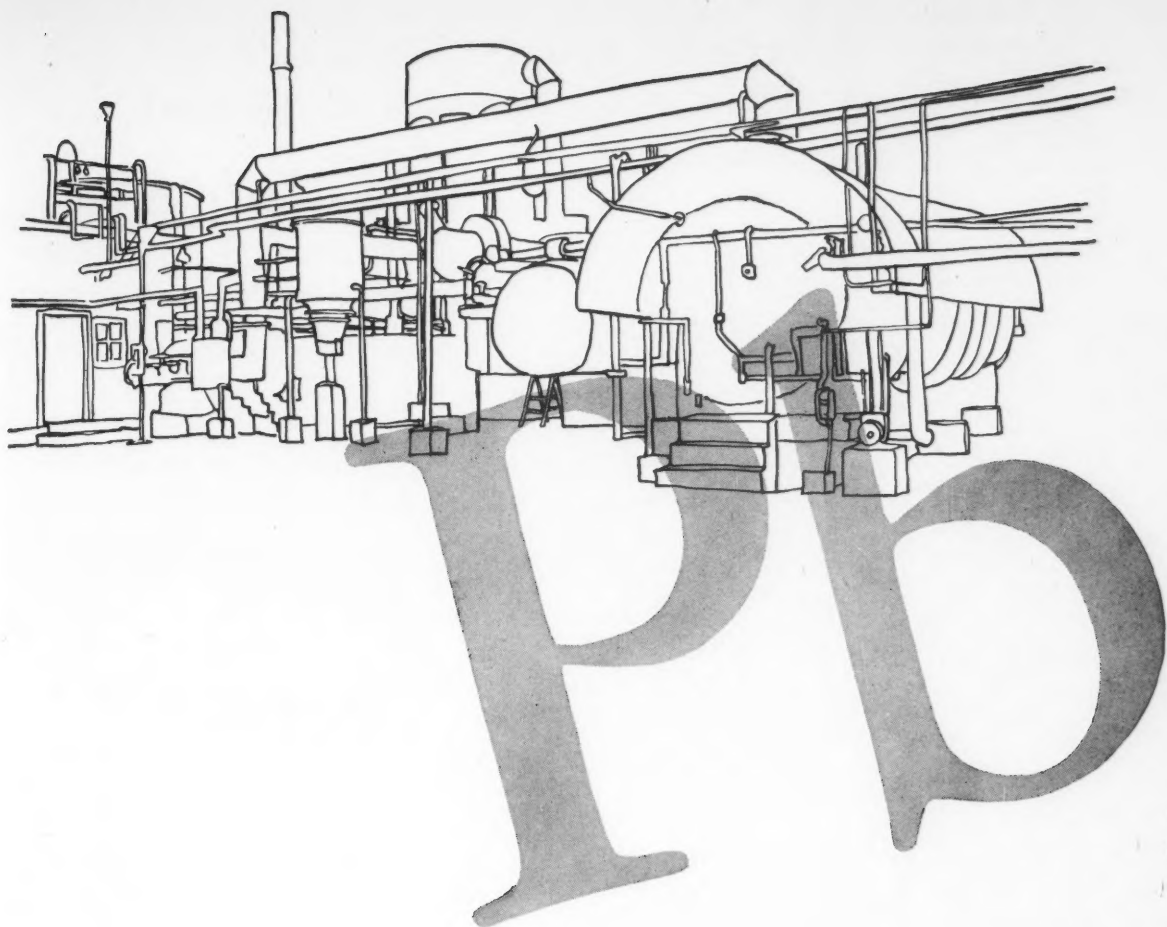
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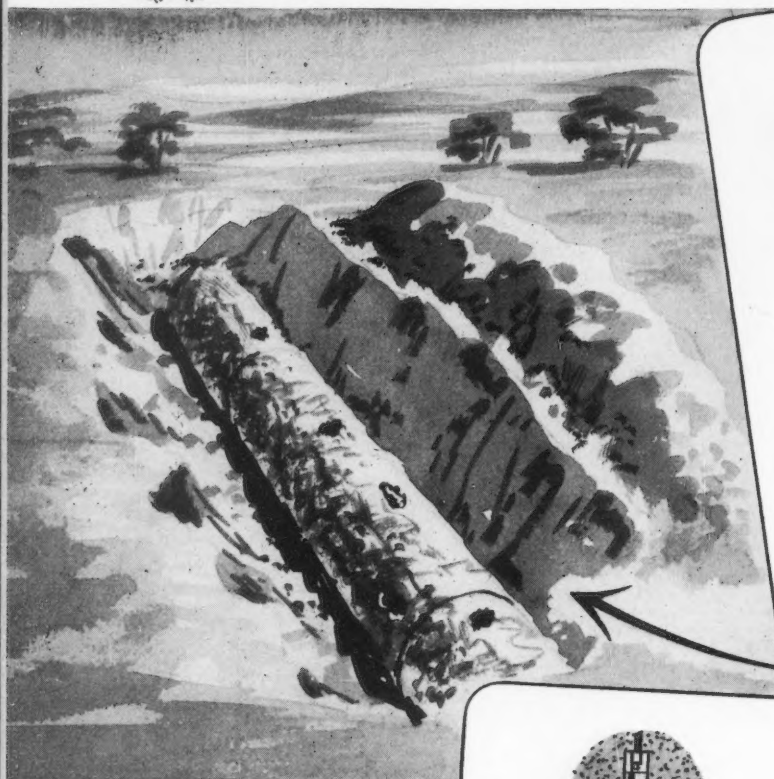


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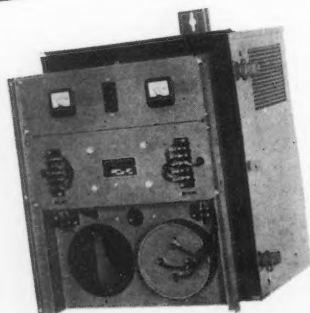
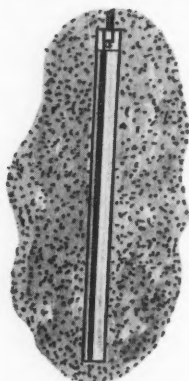
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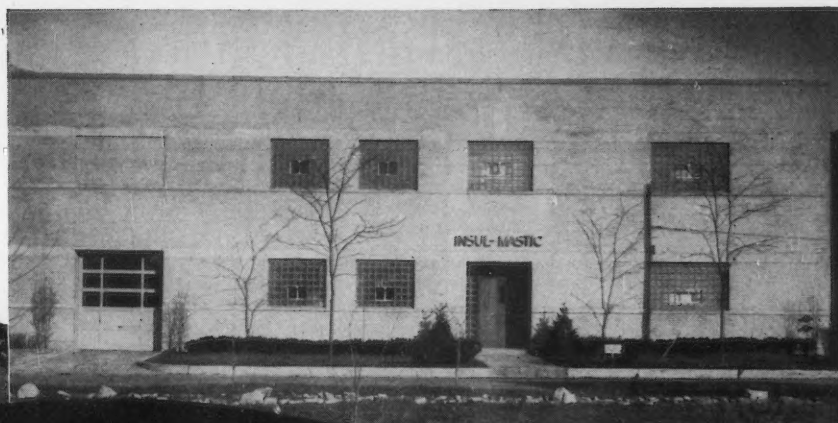
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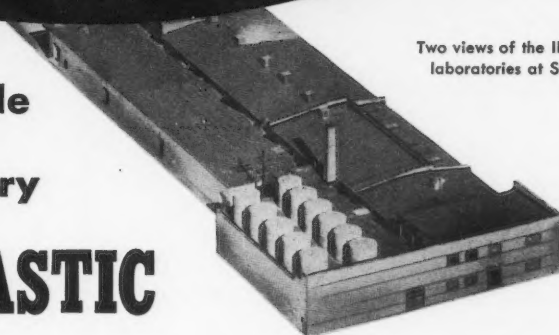
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is a non-profit, scientific and research association of individuals and companies concerned with corrosion or interested in it, whose objects are:

- (a) To promote the prevention of corrosion, thereby curtailing economic waste and conserving natural resources.
- (b) To provide forums and media through which experiences with corrosion and its prevention may be reported, discussed and published for the common good.
- (c) To encourage special study and research to determine the fundamental causes of corrosion, and to develop new or improved techniques for its prevention.
- (d) To correlate study and research on corrosion problems among technical associations to reduce duplication and increase efficiency.
- (e) To promote standardization of terminology, techniques, equipment and design in corrosion control.
- (f) To contribute to industrial and public safety by promoting the prevention of corrosion as a cause of accidents.
- (g) To foster cooperation between individual operators of metallic plant and structures in the joint solution of common corrosion problems.
- (h) To invite a wide diversity of membership, thereby insuring reciprocal benefits between industries and governmental groups as well as between individuals and corporations.

It is an incorporated association without capital stock, chartered under the laws of Texas. Its affairs are governed by a Board of Directors, elected by the general membership. Officers and elected directors are nominated by a nominating committee in accordance with the articles of organization. Election is by the membership.

Inquiries regarding membership, and all general correspondence should be directed to the Executive Secretary at the administrative headquarters of the National Association of Corrosion Engineers at 919 Milam Building, 803 Texas Avenue, Houston 2, Texas.



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TP-7 Plans Publication of Bulletin On Corrosion at Elevated Temperatures

By M.A. SCHEIL*

TECHNICAL PRACTICES Committee 7 has completed a literature review of recent papers dealing with corrosion at elevated temperatures which will be added to the compilation of data on materials for use at temperatures about 400° F now being completed.

The data are being offered to the National Association of Corrosion Engineers for publication in a special Technical Practices Bulletin.

The committee realizes there is probably a wealth of unpublished data on corrosives at operating temperatures in excess of 400 degrees F and it hopes that by this publication members of NACE will cooperate with the committee by making such data available for future issues of the bulletin.

A number of important subjects for discussion and

possible papers at a later date have developed at committee meetings. These include

Corrosion by molten metals;

Effect of alloy substitution and composition restrictions on the high temperature corrosion characteristics of the stainless steels.

In the latter chromium, nickel and molybdenum are involved because of probable limitation orders.

Considerable interest was shown at the last meeting of the committee in possible corrosion effects caused by sigma or some "third phase" precipitate in the highly alloyed stainless steels at 1500° F.

An investigation is under way into the possibilities of a field exposure test for alloys in a special application where more information is important on the effects of carburization, especially on pitting characteristics.

* Chairman, TP-7 Materials for Use at High Temperatures; Director of Metallurgical Research, A. O. Smith Corp., Milwaukee, Wis.

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Rosin Amine - Ethylene Oxide Condensates As Corrosion Inhibitors For Mild Steel in Hydrochloric Acid*

By EDWARD A. BRIED and HARRY M. WINN

THE USE of inhibited acids has increased considerably in recent years due to the development of effective corrosion inhibitors. The steel industry uses inhibited acids to remove mill scale from steel without incurring excessive losses of the metal. Many industries use inhibited acids to clean equipment such as boiler tubes and chemical processing equipment. Inhibited hydrochloric acid is employed for the acidizing of oil wells thus protecting the casing and other underground steel equipment from acid attack during the operation.

Laboratory and field tests of various organic compounds as inhibitors during the past 25 years have indicated that certain nitrogenous organic compounds may be used effectively to reduce the corrosion of metals by inorganic acids. The practical application of such materials as inhibitors was demonstrated as early as 1927 by Speller, Chappell, and Russell¹ when inhibited hot hydrochloric acid was used successfully to remove the rust from the cold water piping system of a 35-story office building in New York City. Laboratory tests by Speller and Chappell² showed that nitrogenous compounds such as aniline, pyridine, and quinoline were among the more effective materials tested. Later Mann, Lauer, and Hultin^{3,4} examined the inhibition effectiveness of 37 different aliphatic and aromatic amines for mild steel in sulfuric acid with good results. Subsequently others including Ch'iao and Mann,⁵ Hackerman and Cook,⁶ and Hackerman and Sudbury⁷ have found amines to be effective as inhibitors for steel in acid solutions.

Although many organic compounds have been found which will retard the attack of acid on steel, the theoretical aspects of the mechanism involved have long been disputed. Several investigators, including Speller and Chappell,² Mann, Lauer, and Hultin,³ and Chappell, Roetheli, and McCarthy,⁸ believed the inhibition was due to the adsorption of large positively charged inhibitor ions at the cathodic areas of the metal. According to this theory the presence of the adsorbed film was instrumental in reducing the cathodic reaction of hydrogen evolution through changes in the cathode potential, increase in hydrogen overvoltage, addition of electrical resistance to current passage, or formation of a film barrier to protect the metal from the acidic medium.



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In recent years a certain amount of evidence has been introduced by various workers^{9,10,11} which points to a general adsorption of the inhibitor at both anodic and cathodic areas. Hackerman and Sudbury⁷ measured the potentials of steel in water and sulfuric acid containing amine additives. Polarization studies indicated that both anodic and cathodic areas were affected by the amines. They postulated that corrosion inhibition was the result of both anodic and cathodic adsorption of the inhibitor. Anodic area inhibition was believed due to the reduced tendency of the iron ions to dissolve as a result of migration of electrons from the metal toward the positively charged adsorbed amine rather than toward cathodic areas within the metal. Cathode area inhibition was believed similar to earlier theories involving increased resistance, overvoltage and diffusion effects.

Regardless of the actual mechanism involved, it is generally agreed that organic inhibitors are adsorbed on the metal surface in a manner such that the attack of the corrosive medium on the metal

* A paper presented at the Seventh Annual Conference and Exhibition, National Association of Corrosion Engineers, New York, N. Y., March 13-16, 1951.

surface is effectively reduced. Nitrogenous organic compounds, and amines in particular, have been used widely with outstanding results. The development of a new amine, Rosin Amine D,* during the past few years has prompted an investigation of its corrosion inhibitive properties in the search for more effective and more economical inhibitors.

Development of Rosin Amine D

Rosin Amine D is a commercially available derivative of wood rosin. Wood rosin as obtained from Southern pipe stumps consists mostly of abietic-type acids, the molecular structure of which is illustrated by I, Figure 1. When this material is subjected to a process of disproportionation an interchange of hydrogen atoms in the cyclic structure occurs which results in two major products, dehydroabietic acid (II, Figure 1) and dihydroabietic acid (III, Figure 1), plus smaller amounts of tetrahydroabietic acid in which the nucleus is fully saturated. These three materials are more stable than the original acid in that they more effectively resist oxidation. The preparation of Rosin Amine D¹² from this mixture may be illustrated by following the reactions of one of its parent constituents, i.e., dehydroabietic acid, keeping in mind the fact that the other resin acids are modified in a similar manner. Successive treatments of dehydroabietic acid convert the carboxyl group of this molecule to the amine as shown in Figure 2. Dehydroabietic acid when treated with ammonia forms dehydroabietonitrile (IV, Figure 2), the ammonium salt of the acid presumably being an intermediate in the process. This nitrile when hydrogenated yields dehydroabietylamine. This product together with dihydroabietylamine and tetrahydroabietylamine form

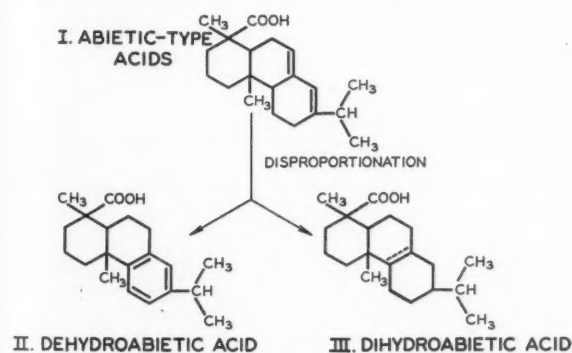


Figure 1—Molecular structure of abietic-type acid and its disproportionated products.

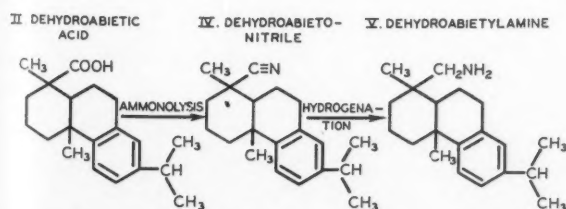


Figure 2—Preparation of dehydroabietylamine from dehydroabietic acid.

* RAD used herein refers to Rosin Amine D.

Abstract

The use of inhibited acids, especially hydrochloric acid, in applications such as metal cleaning and oil well acidizing has increased considerably in recent years due to the development of effective corrosion inhibitors. Organic nitrogen compounds, particularly amines, have long been known to be effective as HCl inhibitors for steel presumably because of their ability to adsorb on the metal surface, thus forming a protective layer.

The development of an amine derivative of rosin led to an evaluation of this product as an HCl inhibitor. Good results were obtained, but the relatively low solubility of rosin amine in hydrochloric acid imposed a concentration limitation. It was found that condensation of the amine with ethylene oxide formed oxyethylated amines which possessed good solubility in HCl and good corrosion inhibition. Even more important were the discoveries that the oxyethylated amines would act as solubilizing agents for up to 15 percent of their weight of free amine, and that addition of free amine to the oxyethylated amines improved their inhibitive properties.

The optimum ethylene oxide content was determined by evaluating a series of condensates containing from one to 31 moles ethylene oxide per mole of rosin amine. The 5-mole condensate was found to be optimum from the standpoint of both inhibition efficiency and acid solubility. The addition of various amounts of free amine to the condensates improved their efficiencies and resulted in very good protection at exceedingly low concentrations. For example, the 5-mole condensate containing 15 percent free amine gave penetration values of 0.130 and 0.159 inch per year at concentrations of 0.20 and 0.05 percent as compared to about 17.0 inches per year for the controls. Test conditions involved mild steel in 15 percent HCl at 165° F for four hours.

The 5-mole condensate containing 15 percent free amine was further evaluated at 0.20 percent concentration by varying both the acid concentration and contact time. Weight losses of mild steel in both inhibited and control acids were determined at 10 time intervals from eight to 240 minutes in 5, 10 and 15 percent HCl. Curves of corrosion rates plotted as a function of time show that in the uninhibited acids the rate increased rapidly for about 40 minutes, then increased slowly for the duration of the tests. In inhibited acids curves of corrosion as a function of time indicate a maximum rate at the shortest time intervals, and that the rate decreases logarithmically as a function of time. This is believed to be due to increased adsorption of the inhibitor during the course of the test.

the major constituents of Rosin Amine D when produced from disproportionated rosin.

Rosin Amine D is a light-colored liquid, insoluble in water but soluble in many organic solvents. Preliminary tests of this material as an inhibitor for mild steel in hydrochloric acid showed definite promise, but the desired effectiveness was not obtained due to concentration limitations imposed by the relatively low solubility of Rosin Amine D in the acid. Methods of solubilizing the amine^{13,14} were found by reacting it with various amounts of ethylene oxide to form oxyethylated amines. Figure 3 illustrates the type of product which may be obtained by one of these methods. In this illustration one of the constituents of Rosin Amine D, i.e., dehydroabietylamine, has been selected to show the over-all reaction, but it should be noted that the other amines derived from disproportionated rosin such as dihydroabietylamine and tetrahydroabietylamine are similarly modified. Products of this type were found to have improved corrosion inhibition properties in mineral acids and natural brines.¹⁵ When Rosin Amine D

reacts with ethylene oxide, both of the hydrogen atoms on the amino nitrogen may be replaced with oxyethylene groups, and the oxyethylene groups may then continue to chain out in two branches. The resulting products are illustrative of Polyethanol RAD condensates, and they may range from free-flowing liquids to hard, waxy solids depending upon the ethylene oxide content.

Method of Testing for Inhibition

The object of this investigation was to screen a wide range of Polyethanol RAD condensates as corrosion inhibitors in hydrochloric acid and to compare them with a few commercially available inhibitors. The new materials tested included Rosin Amine D and Polyethanol RAD condensates. Also, it was desired to determine whether the addition of various amounts of free Rosin Amine D to the Polyethanol RAD condensates would improve the efficiency of the condensates. For purposes of nomenclature simplification, a four-digit code number system has been used to denote the amount of ethylene oxide and added free amine in these condensates. In each case the first two digits reading from left to right indicate the number of moles of ethylene oxide which have been reacted per mole of Rosin Amine D, and the last two digits indicate the weight percentage of free Rosin Amine D which has been added to the condensates. For example, Polyethanol RAD-0515 is the commercial name for the condensate containing 5 moles of ethylene oxide per mole of Rosin Amine D to which has been added 15 percent free Rosin Amine D. A total of 23 such materials were tested including Rosin Amine D, seven Polyethanol RAD condensates containing from one to 31 moles ethylene oxide, and five Polyethanol RAD condensates containing from five to 31 moles ethylene oxide to each of which was added 5, 10 and 15 percent free Rosin Amine D. For purposes of comparison three additional nitrogenous organic inhibitors were tested. The first compound was dibutylthiourea, which is used commercially. The addition of a wetting agent to dibutylthiourea was found by Cardwell and Eilers¹⁶ to increase the effectiveness of this material, and such a mixture was also tested. The wetting agent was 0.10 percent by volume of Petrowet R, a saturated hydrocarbon sulfonate having an average chain length of 10 carbons. A third inhibitor tested was a commercially available coal tar derivative. Although its composition was unknown, it probably contained one or more of the common coal tar bases such as

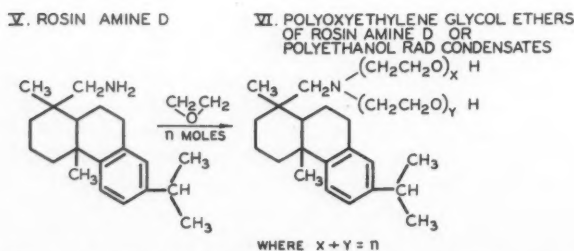


Figure 3—Preparation of Rosin Amine D-ethylene oxide condensates.

pyridine, picoline, lutidine, quinoline and carbazole—all of which are cyclic nitrogen compounds.

The testing procedure consisted of determining the weight loss of cold-rolled mild steel (SAE-1010) coupons measuring 2 x 2 x 0.035 inches after they had been totally immersed in c.p. hydrochloric acid at a constant temperature for a given period of time. Unless stated otherwise, 0.20 percent inhibitor in 15 percent HCl at 165° F for four hours were the test conditions. The coupons used for all tests had been "bright annealed" at the mill and required no special surface preparation for the purposes of these tests other than solvent degreasing. The coupons were run in duplicate in every case and variation in corrosion rates between the two averaged about two percent. In cutting the coupons to size they were sheared on all four sides, and no subsequent treatment was used to relieve any cold-working stresses. After exposure to the acid the coupon was brushed in cold running water to remove corrosion products, rinsed in acetone, and dried before weighing to the nearest 0.1 milligram. The ratio of coupon surface area to acid weight used in each test was 0.0414 sq. in./g aqueous HCl. The weight loss results were converted to units of inches per year corrosion rate (IPY).

Results of Screening Program

The most effective Polyethanol RAD condensate was determined by investigating the effect of varying first the ethylene oxide content, second the added free amine content, and third the inhibitor concentration in the acid.

Variation in Ethylene Oxide Content

A series of seven condensates containing from one to 31 moles of ethylene oxide per mole of Rosin Amine D was tested initially with the results shown

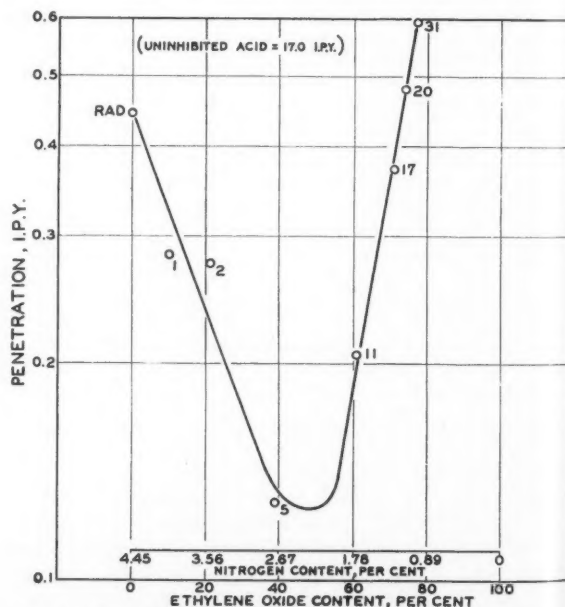


Figure 4—Effect of ethylene oxide content on inhibition efficiency. Test conditions of 0.20 percent inhibitor in 15 percent HCl at 165 degrees F for four hours. (Numbered points indicate moles ethylene oxide reacted per mole RAD.)

in Figure 4. The IPY corrosion rate has been plotted as a function of both ethylene oxide and nitrogen content. It was evident that neither very small nor very large amounts of ethylene oxide were particularly beneficial in improving the effectiveness of Rosin Amine D; however, the condensate containing 5 moles of ethylene oxide was far superior as an inhibitor. The actual corrosion rate for this material was about 0.130 IPY as compared to 17.0 IPY for the control with no inhibitor. The shape of the curve is probably the result of two opposing factors: 1) the increase in solubility of the inhibitor as a result of increasing ethylene oxide content, and 2) the decrease in the number of moles of inhibitor present for adsorption as a result of ethylene oxide dilution. The minimum portion of the curve as represented by Polyethanol RAD-0500 apparently represents an optimum amount of ethylene oxide addition such that the combination of the characteristics of solubility, molecular size and nitrogen available for adsorption to the metal afford the best protection. It is of interest to note that good solubility in acid was obtained with Polyethanol RAD-0500. For solubility in water, approximately 10 moles of ethylene oxide are required.

Variation in Free Rosin Amine D Content

It was found that free Rosin Amine D, which possesses extremely limited solubility in water, could be solubilized in both water and brine by the addition of various amounts of the nonionic Polyethanol RAD condensates. For example, 0.03 percent Rosin Amine D can be solubilized in water by adding 0.17 percent Polyethanol RAD-1100. Because of this unique property, additions of 5, 10 and 15 percent free Rosin Amine D were made to the Polyethanol RAD condensates and the mixtures were tested as inhibitors in HCl. The results, as illustrated in Figure 5, showed that the added free amine improved the efficiency of the inhibitor in most cases. The improvement was particularly great for the higher ethylene oxide condensates whereas Polyethanol RAD-0500 was little affected by the free amine. Apparently the higher ethylene oxide condensates solubilized a portion of the added Rosin Amine D and thus improved their effectiveness; however, in no case were any of the mixtures so effective as Polyethanol RAD-0500 with or without added free amine.

Variation in Inhibitor Concentration

As a final check to single out the most efficient inhibitor, several of the more effective materials determined in the previous tests were again tested at reduced inhibitor concentrations. Materials included were Polyethanol RAD-0500, 0515, 1110, 1715, 2015 and 3115. For purposes of comparison, dibutylthiourea and dibutylthiourea containing a wetting agent were tested under similar conditions. Concentrations of 0.20, 0.15, 0.10 and 0.05 percent inhibitor in 15 percent HCl at 165° F for four hours were used. The results are shown in Figure 6. It was found that Polyethanol RAD-0500, 1110, 1715, 2015 and 3115 all gave very similar inhibition at reduced concentrations and are represented by the single curve labeled

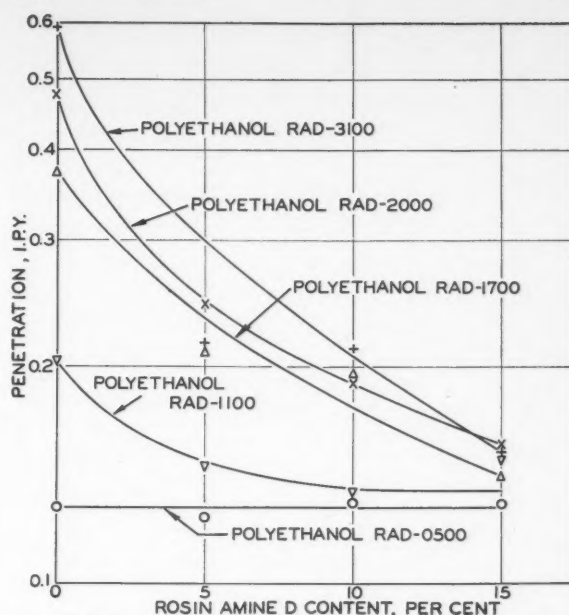


Figure 5—Effect of free Rosin Amine D content on inhibition efficiency. Test conditions of 0.20 percent inhibitor in 15 percent HCl at 165 degrees F for four hours.

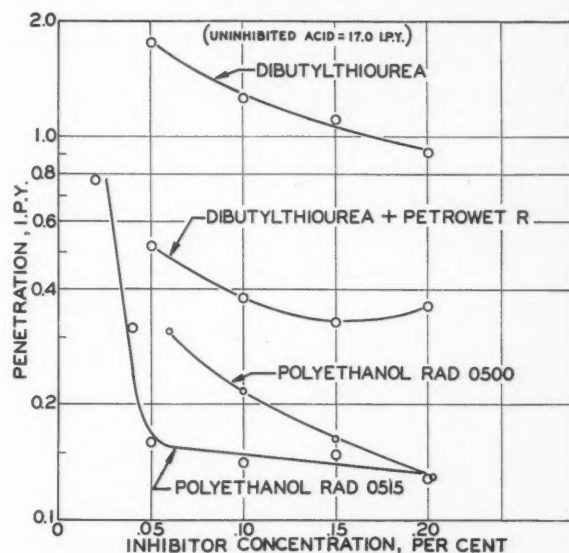


Figure 6—Effect of inhibitor concentration on inhibitor efficiency. Test conditions of 15 percent HCl at 165 degrees F for four hours.

Polyethanol RAD-0500. Dibutylthiourea alone was a poor inhibitor, but the addition of Petrowet R greatly increased its effectiveness. Polyethanol RAD-0515 was found to be remarkably effective at concentrations as low as 0.05 percent where a corrosion rate of 0.159 IPY was obtained. When the concentration of the inhibitor was further reduced to 0.04 and 0.02 percent the corrosion rate increased rapidly indicating that 0.05 percent was about the critical concentration necessary to insure protection under the test conditions.

Further Evaluation of Polyethanol RAD-0515

Having determined that Polyethanol RAD-0515

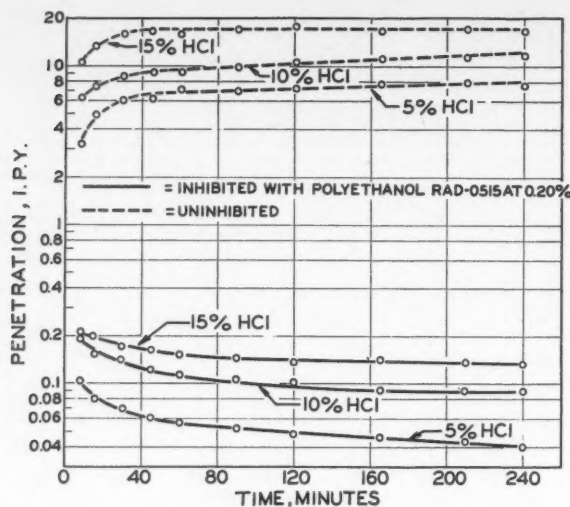


Figure 7—Corrosion of mild steel by inhibited and uninhibited HCl at 165 degrees F as a function of acid concentration and time.

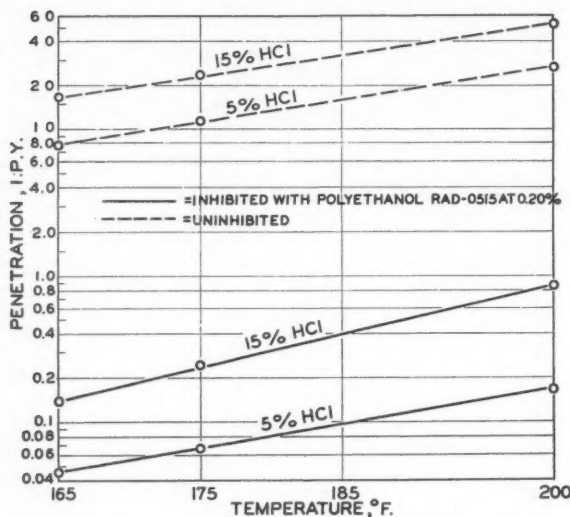


Figure 8—Corrosion of mild steel by inhibited and uninhibited HCl as a function of temperature.

was the most effective inhibitor, it was desired to further evaluate this material under varying conditions of acid strength, contact time and temperature.

Acid Strength and Contact Time

A series of tests were made using both inhibited and uninhibited hydrochloric acid at strengths of 5, 10, and 15 percent concentration in which corrosion rates were determined at various time intervals between eight and 240 minutes. The acid temperature was held constant at 165° F, and the inhibitor concentration was 0.20 percent. The results are shown in Figure 7. The corrosion rates for the uninhibited acids were at a minimum for initial contact times but increased rapidly for about the first 40 minutes after which the rates appeared to increase exponentially with time. The lower corrosion rates for the initial contact times are possibly due to a protective surface

characteristic imparted to the steel during fabrication.

The initial corrosion rates of the inhibited acids were found to be maximums which decreased gradually until an exponential decrease was observed after about 80 minutes. It is postulated that the first portion of the curves reflects the intermediate stages of the inhibitor diffusion-adsorption mechanism equilibrium during which maximum inhibitor effectiveness is gradually being attained. Once equilibrium is attained, the corrosion rate should be a function of the changes in acid concentration and surface area of the metal. In view of the negative slopes actually obtained at the longer contact times, it appears likely that equilibrium has not been completely attained after three to four hours, particularly in the case of the five percent acid. Changes in acid concentration and metal surface area are believed to be too small to account for the negative slopes.

In comparing the inhibited and uninhibited acid corrosion rates at the longest contact times, it is seen that values of 0.04, 0.09, 0.13 IPY and 8.0, 11.5, 17.0 IPY are found for the 5, 10 and 15 percent acids, respectively. The reduction in corrosion rate in each case amounts to 99.50, 99.22 and 99.24 percent.

Temperature

The effect of temperature within the range of 165° F to 200° F was investigated using both inhibited and uninhibited 5 and 15 percent hydrochloric acid. Contact time in this instance was three hours. As shown in Figure 8 the corrosion rates for each of the four acid solutions increased exponentially as a function of the temperature. These curves are all approximately parallel with the exception of the inhibited 15 percent acid, which has a slightly steeper slope. However, even at 200° F the corrosion rates in IPY for the inhibited and uninhibited 15 percent acids are 0.85 and 52.00 respectively or a protection of 98.37 percent. The higher temperature coefficient of 15 percent inhibited acid, as shown by the steeper slope, indicates that a certain amount of loss of inhibitor efficiency is observed in 15 percent acid that is not found in five percent acid at higher temperatures.

Commercial Inhibitor

In addition to the dibutylthiourea inhibitors mentioned earlier, a commercial coal tar derivative was tested for comparative efficiency as an inhibitor. Test conditions were 0.20 percent inhibitor in 15 percent hydrochloric acid at 165° F for four hours. The corrosion rate was found to be 0.158 IPY as compared to 0.130 IPY for Polyethanol RAD-0515.

Conclusion

The condensates of ethylene oxide with Rosin Amine D containing from one to 31 moles of ethylene oxide per mole of Rosin Amine D were found to act as corrosion inhibitors for mild steel in hydrochloric acid. It was found that the condensate containing five moles of ethylene oxide (Polyethanol RAD-0500) was the most efficient with acid solubility, nitrogen content and molecular configuration being optimum at this point. The addition of free amine to this condensate (to give Polyethanol RAD-

0515) was shown to enhance its inhibitive properties, especially when the inhibitor was reduced in concentration from 0.20 to 0.05 percent. Further investigation of this inhibition under conditions of varying acid concentrations and contact times showed that after equilibrium conditions were established the corrosion rates for 5, 10 and 15 percent HCl as measured in inches per year penetration decreased exponentially with time. At temperatures as high as 200° F Polyethanol RAD-0515 was an effective inhibitor in 15 percent HCl giving 98.37 percent protection. Other nitrogenous organic materials including dibutylthiourea with and without a wetting agent and a commercial coal tar derivative were found to be less efficient as inhibitors under the conditions tested.

The testing conditions for this investigation were chosen with the purpose of carrying out a large number of simplified corrosion tests for screening several possible inhibitors. For example, the effects of dissolved oxygen, agitation, ratio of acid volume to metal surface area, specially prepared metal surfaces and stresses resulting from cold-working were not investigated. The influence of Polyethanol RAD-0515 upon the hydrogen embrittlement of steel is currently being investigated as is the addition of solvents to this inhibitor.

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INDUSTRIAL APPLICATIONS

Polyethanol RAD-0515 is suggested for use as an inhibitor in hydrochloric acid employed for oil well acidizing, industrial metal cleaning, pickling of steel and other industrial uses of hydrochloric acid.

Some of the other Polyethanol RAD condensates are receiving industrial attention as inhibitors for other purposes. Polyethanol RAD-1110, because of its better solubility in natural brines, is currently undergoing experimental field tests as an inhibitor of corrosion in wells producing sour crude oil and natural brine as well as in flood waters for the secondary recovery of oil. At concentrations of 100 ppm and lower in the well fluid it appears to arrest hydrogen sulfide and carbon dioxide corrosion.

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Testing Inhibitors of Brine Drippings Corrosion Of Railway Tracks and Equipment*

By G. M. MAGEE

MANY PRODUCTS shipped in refrigerator cars on the railways require lower temperatures than can be obtained with ice alone. Inasmuch as ordinary salt is by far the cheapest chemical that can be added with the ice to lower the melting point, it has been the practice for many years to use salt with ice to lower the temperatures as required for refrigeration. Ordinarily, the ice and salt mixture is contained in open bunkers at each end of the refrigerator car and the brine is discharged from the bunkers through nozzles at each corner of the car on to the track structure. Most of the shipments that require salt are iced with a saturated salt solution in which the salt constitutes about 25 percent of the brine. When the brine drips from the bunker nozzle as the trains are traveling at high speeds, it is caught by the wind and sprayed over certain parts of the track and bridge structures and parts of the frame and trucks of the refrigerator cars. The annual corrosion loss to the railways from the damage done by this brine dripping cannot be accurately evaluated, but it has been estimated that the damage to track and bridge structures probably exceed \$8,000,000 annually, and the damage to the refrigerator cars is perhaps one-half of this amount.

Consideration has been given to various methods of preventing this corrosion cost. These have included brine retention tanks to hold the brine and discharge it at selected points on the railroad and also, the use of mechanical refrigeration. Both of these methods have serious economic disadvantages from the standpoint of added investment and operating costs together with the fact that refrigerator cars are actually used in service requiring brine a relatively small percentage of the time. Thus, the major part of the time the added investment would be of no value and the additional weight would result in increased hauling cost.

In 1937, the suggestion was made that perhaps a corrosion inhibitor could be used with the salt when icing the cars, which would effectively protect the track, bridge and car structure from this brine corrosion. Accordingly, plans were made to conduct laboratory tests on various inhibitors that might be used for this purpose. Arrangements were made with the laboratories of four railways, the Chesapeake and Ohio, Denver and Rio Grande Western, Milwaukee and Santa Fe to carry out a comprehensive series of laboratory tests. The tests were conducted in a similar manner on each railway, except that

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Since 1937 with Association of American Railroads with headquarters in Chicago, he has directed research activities on way and structures.



Abstract

A joint committee from the Engineering and Mechanical Divisions of the Association of American Railroads has been sponsoring research work for some years aimed at finding a means of preventing damage from refrigerator car brine drippings to the track, bridges and car itself. Initial studies indicated addition of sodium dichromate neutralized with soda ash to the salt and ice in the bunkers of the cars would effectively prevent corrosion from brine drippings. However, because of the toxicity of the dichromate it was found necessary to add the inhibitor externally of the car by passing the brine drippings through a suitable filter in order to avoid contamination of the lading. Further work indicated development of such a filter was possible but the cost of servicing filters on each refrigerator car made the use of dichromate appear questionable economically.

Studies with other inhibitors more recently developed have indicated Sodium Polyphos will be equally effective from the standpoint of preventing corrosion, and since it does not have the undesirable toxicity, it can be added directly with the salt. The cost of Sodium Polyphos as an inhibitor is not much greater than dichromate for equal protection, so it appears it will offer much more economical means of controlling corrosion. Additional work is necessary to determine the most effective inhibitor concentration and most economical method of application.

salt solutions of 5, 10 and 15 percent and saturated were used, respectively.

Careful consideration was given to the type of test specimen used and the method of conducting the test. It was decided to use a test specimen of low carbon steel, 3 inches wide by 6 inches long by 3/16-inch thick, bent up at 3 1/2 inches from one end to provide a slight slope corresponding to that of rail base and ends of tie plates. A round hole was drilled near the center of the specimen so that the brine solution could also come in contact with the bottom of the specimen where it rested on a treated wood plank corresponding to treated ties used in track.

* A paper presented at the Seventh Annual Conference and Exhibition, National Association of Corrosion Engineers, New York, N. Y., March 13-16, 1951.

Brine drippings were dripped on each specimen from burettes in the amount of 0.5 cc twice daily. Tests were continuous over a period of two months and the amount of metal lost by corrosion was determined by comparing the weight of the specimen before and after the tests, the corrosion products being removed by an approved process.

These tests indicated that some of the inhibitors included in the tests might indeed be effective in controlling corrosion. Accordingly, a more extensive program was planned using several additional inhibitors, particularly those that were attractive because of their low cost; to extend the test period to 90 days; and also to make certain improvements in the test technique that were desirable based upon the experience of the previous series.

For the second series of tests it was decided that it would be desirable to change the type of the test specimen. The amount of brine applied was more than would be contained on the top surface of the specimen so that a portion ran off the sides, which did not seem an accurate comparative procedure. Also, the amount that went through the hole in the specimen and collected between the bottom of the specimen and the treated wood surface was obviously an uncontrolled amount. For the second series of tests all test specimens for all four laboratories were taken from the same piece of steel. Each test specimen consisted of two disks, approximately 2 inches in diameter and $\frac{1}{8}$ -inch thick. To make one test specimen, two disks were placed together flatwise and sealed together by coating their entire circumference with a mastic. As in the previous tests the specimens were placed on a creosoted plank.

The detailed procedure for the tests was as follows: First, for each specimen 1 cc of brine solution was dripped on the plank within the area covered by the specimen and the specimen replaced. Next, 1 cc of solution was dripped on the top surface of the specimen and spread over the entire surface with a glass rod without disturbing the corrosion film. Each evening 1 cc of the brine solution was applied to the top surface of the top specimen only, but not to the bottom surface. Twice each week, the soluble solutions were washed from the top and bottom surface of each specimen with distilled water and a washing bottle.

Each of the four laboratories made one series of tests with a 10 percent salt solution and one series with either a 5 percent, 15 percent, 20 percent or saturated, respectively. In these tests several types of inhibitors were included with various concentrations of each type of inhibitor. The results from these laboratory tests consistently indicated that the best performance of the inhibitors tested could be expected from the use of sodium dichromate neutralized with soda ash. Also, the tests indicated that a concentration of approximately three grams per liter of sodium dichromate in the brine solution would give very effective protection. The tests were quite encouraging in that the results showed that the corrosion from the brine containing this inhibitor was even less than that from distilled water alone.

Although these laboratory tests were quite en-

couraging, nevertheless several questions remained to be determined regarding the use of the inhibitor in actual service conditions. One question was whether the inhibitor could be added directly with the salt in icing the cars and obtain the desired concentration in the brine as the ice melted during the period between re-icing. The other question was whether the inhibitor could be expected to give the same protection on rail and tie plates outdoors and exposed to the weather as it did to the steel test specimens in the laboratory.

To answer the first of these two questions, arrangements were made with the Santa Fe to add the inhibitor with the salt to a refrigerator car used in a regular service run from Los Angeles to Chicago. Some preliminary tests were made to determine whether the addition of the inhibitor to the salt would impair its refrigerating qualities. These showed that the small amount of the inhibitor used had no measurable effect on the efficiency of the salt. A standard refrigerator car was selected for the test run and was placed at the Santa Fe Hobart Ice Plant at Los Angeles. An inhibitor was added to the salt during the pre-icing and pre-cooling of the car prior to receiving the lading. Samples of the brine drippings were collected at intervals throughout the day and night and at regular intervals of time thereafter while the car was being loaded and during its movement from Los Angeles to Chicago. This entire test period extended through eight days. The inhibitor was added with the salt at each re-icing period enroute. After the completion of the test run the brine samples were analyzed for salt concentration, sodium dichromate concentration and pH value. Although it was found that there was some variation of the inhibitor concentration during the run, in general it appeared that there was a sufficient quantity of inhibitor in the brine drippings to give effective protection.

The second question was answered by conducting a track test on the Milwaukee Railroad near their laboratory at Milwaukee, Wisc., in which a short section of rail and tie plates was sprayed daily for a 90-day period with salt solution and a corresponding section was sprayed daily for the same period with a salt solution containing the sodium dichromate inhibitor. Weight loss was determined by weighing six tie plates in each sprayed section before and after the test and also by weighing two small 2-inch disks which were placed on top of the outer end of each tie plate. The results from this test were quite encouraging because not only did the tie plates and test disks which were sprayed with salt solution containing the inhibitor, lose far less weight from corrosion than those sprayed with salt solution alone, but they even showed less corrosion loss than companion tie plates subjected to only atmospheric corrosion through the same period, without any salt spray.

Arrangements were next made to select a refrigerator car in shuttle service between Cincinnati and New York City and treat one end of the car continuously with salt containing sodium dichromate, the other end to be treated only with regular salt. It was the object of this test to determine the protection af-

forded to the refrigerator car understructure and trucks by the inhibitor. However, shortly after starting this test the shippers objected to the use of sodium dichromate because of its toxicity and the possibility that claims for damaged lading would result because of its use. The entire subject was then referred to the Medical Section of the Association and advice was received that if a toxic inhibitor of this nature were used it would be necessary to add the inhibitor to the brine in a manner that would prevent any possible contact of the inhibitor with the lading.

In order to accomplish this the only practical solution appeared to be the design of a suitable filter on the discharge end of each bunker nozzle to add the desired amount of inhibitor to the brine after it had left the interior of the car and before it was finally discharged. Accordingly, an agreement was made between the AAR and Armour Research Foundation for the development of a suitable filter and the further consideration of other inhibitors that might be equally suitable and non-toxic. An extensive research program was carried out by ARF in which several types of filters were designed and tested in laboratory experiments. These laboratory experiments indicated that a design of filter could be made that would operate satisfactorily. However, consideration of the economic factors involved including the labor for servicing the filters and the cost of the inhibitor indicated that this method of adding the inhibitor to the brine was too expensive to receive further consideration. Accordingly, efforts were concentrated upon tests with types of non-toxic inhibitors. It was found that there were some inhibitors available which would give practically as good protection at substantially the same cost as the toxic sodium dichromate.

The most promising of these inhibitors was Sodium Polyphos, the trade name of a glassy phosphate, intermediate in composition between sodium hexameta-phosphate and sodium tetrphosphate. Almost equally good results were obtained with disodium phosphate. Tests with the Sodium Polyphos indicated that the corrosion rate was reduced 68 percent

with a concentration of two grams per liter of brine, 80 percent with three grams per liter of brine and 86 percent with four grams per liter. Also, a laboratory test was made in which 200 lbs. of ice was melted containing 10 lb. of salt and 0.33 lb. of Sodium Polyphos. It was found that the inhibitor concentration in the discharged brine corresponded reasonably well with the salt concentration during the melting time of approximately 24 hours.

An economic study was then made wherein the cost for various concentrations of inhibitor was balanced against the estimated corrosion loss based upon the relative effectiveness of the concentrations as determined from the laboratory tests. This economic study indicated that the addition of two grams of Sodium Polyphos per liter of brine would be the most desirable concentration to use and might be expected to effect a reduction of approximately 50 percent in the annual corrosion loss of the railways due to brine drippings from refrigerator cars.

More research must be conducted before definite recommendations can be made for use of the inhibitor in icing refrigerator cars. Laboratory tests have only been made with specimens of high carbon steel over a two months' period. These tests should be extended for at least six months and should also include low carbon steel similar to that used in track spikes and bridge structures and medium carbon steel corresponding to that used in tie plates. Field investigations including outdoor corrosion tests must be made to verify the laboratory results. Contact must be made with the salt manufacturers to determine the practicability of having the inhibitor added to the salt at the source of manufacture. Also, more definite figures must be obtained on the cost of inhibitor, and labor costs for the addition of the inhibitor to the salt in order to more accurately evaluate the economics of the procedure.

It may be said, however, that the results of the research work are very promising and indicate that a substantial reduction may be made in the annual corrosion loss of the railways resulting from brine drippings from refrigerator cars which will save the industry several millions of dollars annually.

Some Applications of Organic Corrosion Inhibitors In the Petroleum Industry*

By CHARLES M. BLAIR, JR.

WITHIN RECENT YEARS, the use of organic corrosion inhibitors has become an important means of reducing corrosion losses in the petroleum industry. It is the purpose of the present paper to discuss a variety of applications of corrosion inhibitors in the petroleum industry with particular emphasis on the use of such inhibitors in oil and gas production work.

Corrosion of a very severe type has long plagued the producer of oil, causing deterioration of casing, tubing, rods, pumps, strainers, well-head equipment, flow lines and other lease equipment and leading also to losses from shut-down, labor costs and damage to producing formations. The problem has been most noticeable in fields producing brine and hydrogen sulfide along with the oil, but is not confined to such fields. Some so-called "sweet oil" areas experience severe corrosion,¹ and a large percentage of gas and gas-condensate wells undergo corrosive attack.²

The type of corrosion encountered in typical oil and gas wells differs in several respects from that generally observed in other industries. Attack takes place under reducing—or at least under anaerobic—conditions; usually two, and sometimes three, or four, phases are in contact with the metal; and the corrosion products do not form thick, or highly adherent films. Attack appears to originate from acidic constituents such as hydrogen sulfide, carbon dioxide or organic acids in the oil, brine or gas and is abetted by high temperatures, turbulence and, to some extent, erosion and mechanical abrasion.

These severe and unusual conditions explain, in part, the time-lag between recognition of the problem and the development of inhibitors capable of giving a high degree of protection at a reasonable cost.

Probably the earliest efforts at corrosion inhibition in oil wells involved the use of inorganic alkaline reagents. Sodium hydroxide or soda ash solutions were introduced down the casing annulus on the theory that they would neutralize acidic constituents of the oil or brine, raise the pH of the brine and thus lessen attack. Such reagents did some good, but large quantities were required for beneficial results and the reagents frequently caused precipitation of scale in the tubing. In general, such treatment was not economically sound. Chromate solutions were also used³ but were inoperative in systems contain-



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Abstract

The application of organic inhibitors for the abatement of corrosion in the petroleum industry is a relatively recent development. The history of this development is briefly reviewed, with particular emphasis on the application of corrosion preventives in oil and gas wells.

The mechanics of inhibitor use and recommended methods of application are discussed.

Corrosion rate data are presented for a number of typical systems in which organic corrosion inhibitors are used. These systems include oil wells, gas condensate wells, gas lines, water injection systems, gasoline plant stripping columns and refinery processing units.

The question of the mechanism of the action of organic inhibitors in reducing corrosion rates of metals is briefly considered. Laboratory and field data on the relation between inhibitor concentration and corrosion rate are analyzed and compared with the predictions of corrosion rate derived from adsorption theory.

ing hydrogen sulfide. Even in sweet oil systems, chromates are generally reduced to some extent, leading to unreliable action, precipitation of scale and formation of refractory emulsions. However, chromates still find occasional successful application in gas well where reducing conditions are not severe.

An early use of organic inhibitors appears in the application of sodium cresylate,⁴ sodium phenolate and similar alkali salts of weak organic bases. Results with these reagents were apparently similar to those obtained with alkalies.

It became apparent from these early experiences that a practical inhibitor must be effective at concentration far below that required for removal of acidic corrodants, and should, therefore, be a material capable of forming an adherent film on the metal in

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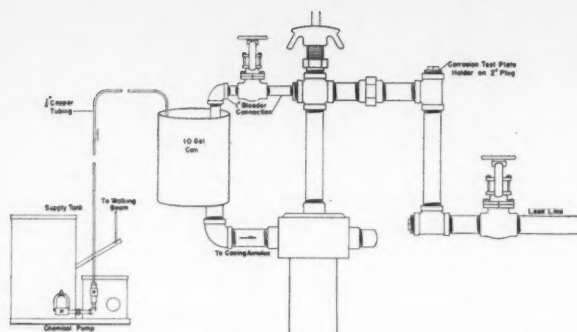


Figure 1—Continuous inhibitor injection system for pumping well with open casing.

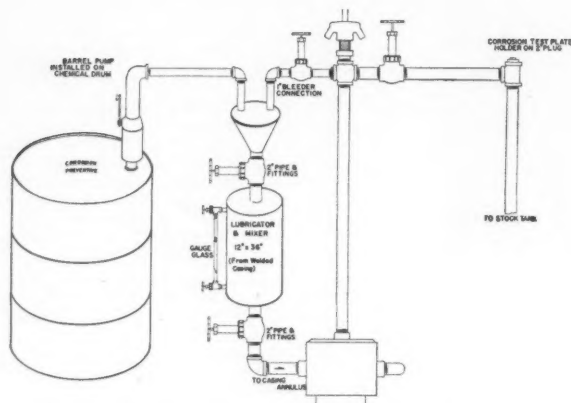


Figure 2—Typical hook-up for dumping inhibitor down casing.

the presence of both oil and brine or otherwise interfering with the corrosion cell reactions when present in relatively low concentration.

Formaldehyde was found to be an effective inhibitor in systems containing hydrogen sulfide⁵ and has found wide commercial use. Except for this simple organic molecule, development of inhibitors has led to the use of relatively complex, high molecular weight compounds. Reagents which have been found to be effective to at least some degree are characterized by high molecular weight and a semi-polar structure involving a large hydrocarbon radical and a polar group containing elements such as oxygen, sulphur or nitrogen. Examples of such products which have been used or proposed for oil-field inhibitor use include naphthenic acids, bone oil, Turkey Red oil, crude coal tar bases, aliphatic and cycloaliphatic amines, quaternary ammonium salts, esters of high-molal polycarboxylic acids, ester alcohols, ether alcohols, pyrrolidine derivatives, and various semi-polar heterocyclic ring compounds.^{6, 7, 8, 9}

The general utility of such organic inhibitors has been demonstrated by the results obtained in a wide variety of wells and fields.^{8, 10, 11, 12}

Mechanics of Application

Organic corrosion preventives are now available in both liquid and solid stick form, the former generally being used in wells having an open flow string of casing communicating with the tubing, as in the

case of most ordinary oil wells and in many gas wells. The solid stick inhibitor is usually used where the casing is closed by a packer or other means, as in the case of some oil wells and many gas and gas-condensate wells.

In wells with open casing, a liquid preventive is almost invariably applied by pumping, dumping or lubricating the fluid down the casing annulus. The fluid flows down the annulus, eventually reaching bottom where it is swept upward through the tubing by the production. This procedure insures protection of interior casing and exterior tubing surfaces as well as interior tubing, well-head and flow line surfaces, and represents the most efficient means of utilizing the chemical. The choice of application method in such wells will depend upon well properties and local work practices.

It has been found that certain corrosion preventives may be introduced into a well in discontinuous fashion without any apparent lessening of protective action, provided the intervals between additions do not exceed two or three days. This effect apparently arises from the fact that even though the reagent is dropped into the annulus batchwise, the required travel down the casing extends the arrival at the bottom of the hole over a somewhat longer period, and further to the fact that the inhibitor film, when once established on the metal surface, persists for a considerable period even if no further chemical is added. Eventually, of course, the preventive film will be leached or abraded away, and protection will be lost unless further additions are made. Where batch dumping of preventive is practiced, it appears preferable, although not invariably necessary, that the reagent be diluted with several volumes of oil or water, or, better, that it be flushed down the casing with some of the production fluids, where this operation can be carried out.

Figures 1 and 2 are simplified drawings showing typical methods of inhibitor introduction which have been used successfully at pumping wells. Figure 1 shows an injection system for pumping wells with an open casing, employing a chemical feed pump which introduces the reagent into a mixing can connected to the annulus and into which a portion of the produced fluids may be bled periodically to assist in washing the reagent down the hole. Figure 2 shows a typical arrangement for dumping inhibitor down a well with moderate or low pressure on the casing. A similar apparatus of sturdier construction may be used on high pressure flowing wells, eliminating, if desired, the bleeder connection, and with provision of a pressure equalizing connection with valve between the lubricator and casing.

In the case of high pressure gas and gas-condensate wells, similar methods of inhibitor introduction are applicable, except that lines, lubricators and vessels used must be built approximately to withstand safely the high pressures. Also, careful provision must be made for venting of vessels before filling, and for equalizing pressures with the casing for introduction of liquid inhibitor or solution.

Figure 3 is a schematic drawing of a high pressure lubricator system designed by the Southern Union

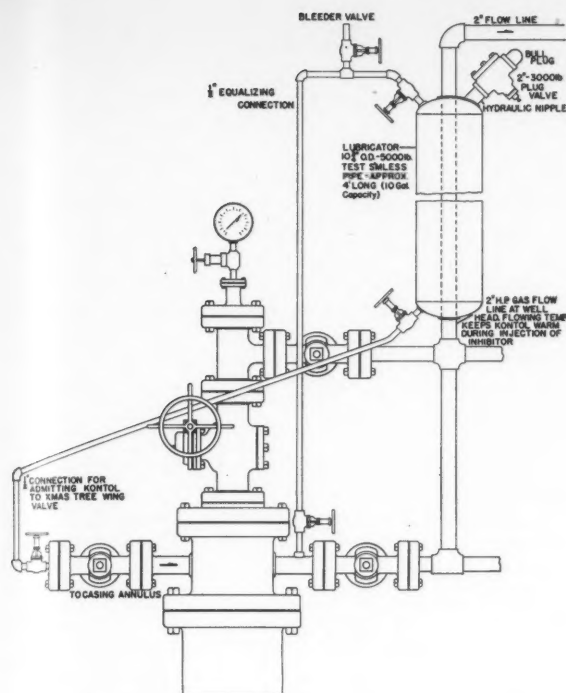


Figure 3—Heated high pressure lubricator for liquid inhibitor (Southern Union Gas Co. design).

Gas Company and successfully used on gas condensate wells. It provides a means of keeping the chemical warm and free flowing which is particularly useful in colder climates.

The problem of treating a considerable number of widely scattered condensate wells has been economically solved by some producers by equipping a truck for corrosion preventive injection.¹² This truck rig is provided with a high pressure pump driven by a power take-off, taking suction from a chemical tank and delivering the reagent through high pressure hose and appropriate check valves and fittings to a companion fitting on the christmas tree which communicates with the casing. A fluid meter in the suction line indicates the amount of inhibitor delivered. By means of this rig, a large number of wells may be quickly treated.

Many gas condensate wells are now completed with packed-off tubing, and in such instances, the methods of chemical injection previously described are inapplicable. Protection of the tubing, well-head and flow lines of such wells can be accomplished by introducing corrosion preventive down the tubing while the well is closed in. By means of a suitable lubricator, liquid reagents may be dumped down the tubing. Generally, however, the time required for the liquid to reach the bottom of the tubing is considered too long, and the shut-in time of the well thus too great, for this method to be practicable. In such cases, solid stick corrosion preventives are available.

Figure 4 shows a type of lubricator used for introduction of stick-type organic inhibitor into the

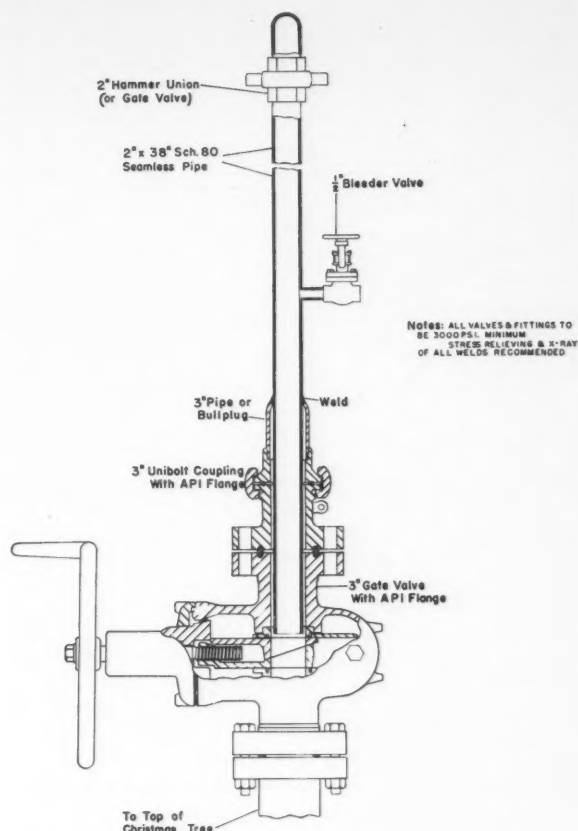


Figure 4—Lubricator for stick-type inhibitor (Continental Oil Co. design).

tubing of wells. This lubricator, designed by the Continental Oil Co., employs a two-inch pipe long enough to hold two sticks. By assembling this tube over a three-inch gate valve, as shown, centering of the sticks with respect to the valve opening is achieved, and hangup of the sticks in the valve is avoided.

In establishing a program of inhibition by means of organic corrosion preventives, it should be recognized that the exact minimum amount of reagent required for protection in a given well or group of wells is subject to experimental determination. Oil and gas wells vary considerably in the degree of corrosion experienced, depending upon the nature of the fluids produced, their quantity, the temperature of the fluids, methods of production, and perhaps other variables not now recognized.

However, some general principles of treatment have evolved during the several years of field use of corrosion preventives. Initial heavy dosing of the well with reagent is usually desirable in order to insure immediate protection of the casing, tubing, wellhead and flow lines. It is desirable to determine the relative corrosion rates in the well before and for some time after treatment is initiated or until a safe minimum dosage rate of corrosion inhibitor is established. For this purpose, weighed steel test plates, such as those described by Gross and An-

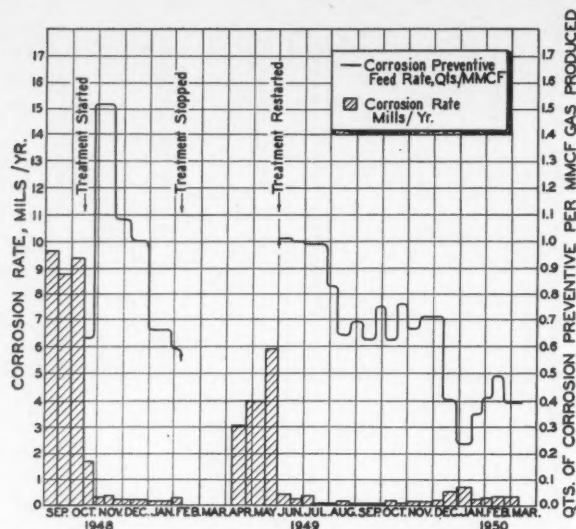


Figure 5—Record of corrosion rate in gas-condensate well before and during treatment with organic inhibitor.

draws¹⁰ are frequently employed. Where the fluids do not contain hydrogen sulfide, determination of the iron content of the produced water is often a suitable means of measuring relative corrosion rates. These methods are helpful in indicating comparative rates of attack, although they may bear no clearly defined relation to corrosion rates of well equipment, per se. Caliper surveys and visual inspection of well equipment may also be used.

Results of Inhibitor Use

The degree of corrosion mitigation possible with properly selected and applied organic corrosion preventives is surprisingly high. Gross and Andrews¹⁰ have described in detail the results obtained in highly corrosive sour pumping wells in West Texas employing organic, semi-polar, heterocyclic inhibitors.⁹ In these wells, corrosion was consistently reduced by more than 90 percent, as determined by weight loss of tubing and rod subs. Reductions by as much as 98 percent or more were obtained in several other cases, employing one part of corrosion preventive per 5000 parts of oil produced. In some of these wells, the ratio of water to oil produced was as high as 10 to 1.

Similar degrees of protection are commonly obtained in gas and gas-condensate wells. Figure 5 shows the relationship between amount of organic corrosion inhibitor used and the corrosion rate in a typical, highly corrosive, condensate well. This well, located in Louisiana, was completed below 8000 feet with an open flow string. It is produced at the rate of about 5 million cubic feet of gas per day, with about 300 barrels of condensate and 20 barrels of water accompanying the gas. Bottom hole temperature is about 240° F. The severe corrosion in this field was indicated by pitted tubing and serious damage to chokes, well-heads, and flow lines.

Prior to and after treatment with chemical preventives the well-head corrosion rate was determined by exposing duplicate weighed steel coupons in the tubing head for periods of from 14 to 24 days. The

initial corrosion rate averaged about 9.5 mils per year. The well was then protected by daily batch-dumping the corrosion preventive dissolved in three parts of distillate down the casing annulus. As shown by the graph, this procedure quickly reduced the well-head corrosion rate to less than 0.3 mpy at a corrosion preventive injection rate of 0.66 quart per Mmcf of gas produced. Chemical injection was then stopped for nearly four months. Even at the end of this period, well-head test coupons were being partly protected, as they exhibited a corrosion rate of 5.9 mpy, or about 62 percent of the original unprotected rate. This fact suggests that some of the chemical was slow in reaching the bottom of the tubing or that the adsorbed film previously established on the metal surfaces of the well was being slowly dead-sorbed to be partly readsorbed on the test coupons.

After corrosion preventive injection was resumed in this well, the corrosion rate was soon reduced to an average of less than 0.2 mpy, using about 0.65 quart of chemical per Mmcf of gas. Reduction of the chemical rate to 0.4 and then to 0.24 quart per Mmcf resulted in a slight increase in corrosion rate, and thus established the minimum injection rate for 98 percent protection at something between 0.4 and 0.65 quart per Mmcf of gas.

TABLE I
History of Corrosion Rate in Gas-Condensate Wells Before and During Treatment with Solid Stick Corrosion Preventive

Date of Measurements	Corrosion Preventive Rate Sticks/MMCF	Corrosion Rate of Steel Coupons MPY	Iron Content of Water PPM
May 5, 1948.....*	None	*	610
May 24, 1948.....	None	*	200
May 17 to June 1.....	None	50.7	250
June 1 to 15.....	None	51.1	250
Average.....	....	50.9	328

Treatment with Corrosion Preventive Initiated Jan. 8, 1949

Period	Corrosion Preventive Rate Sticks/MMCF	Corrosion Rate of Steel Coupons MPY	Iron Content of Water PPM
January 8 to 22, 1949.....	1.0	0.15	**
January 22 to March 5.....	0.66	0.39	4
March 5 to 19.....	0.66	0.21	8
March 19 to April 2.....	0.57	0.34	14
April 2 to 16.....	0.33	0.06	*
April 16 to May 7.....	0.33	0.21	*
May 7 to 21.....	0.33	0.41	10
May 21 to June 4.....	0.33	0.34	**
Average.....	....	0.26	6

* Not determined.

** Zero.

TABLE II
History of Corrosion in Sour Gas Distributing System
Corrosion Inhibitor Introduced at Compressor Discharge

Test Period	Quarts of Inhibitor Used per MMCF of Gas	Corrosion Rates, Mils per Year	
		1.6 Miles from Compressor	3.6 Miles from Compressor
March 10 to March 25, 1949...	*	28.9	31.5
April 20 to May 6.....	2	6.46	3.29
May 6 to May 20.....	2	5.18	4.90
May 20 to June 7.....	2	0.22	3.29
June 7 to June 22.....	2	0.09	0.72
June 22 to July 6.....	2	0.33	0.26
July 6 to July 20.....	2	0.54	0.25
July 20 to August 3.....	2	0.51	0.14
August 3 to August 31.....	2	0.27	0.16
August 31 to October 12.....	2	0.15	0.08
October 12 to November 22.....	2	0.34	0.15
November 22 to December 29.....	2	0.16	0.22

* None.

Many less corrosive condensate wells are readily protected at chemical injection rates of 0.25 quart or less per Mmcf of gas.

A typical example of protection from corrosion by means of a solid stick form of preventive is shown in Table I. These data were obtained in the treatment of a highly corrosive gas condensate well in Southern Louisiana. This well is approximately 9000 feet deep, and is completed with a tubing packer which closes the casing annulus. It has a bottom hole temperature of 250° F, a well-head pressure of 3000 psi, and produces daily about 3 Mmcf of gas, 70 barrels of distillate and 2 barrels of water.

Corrosion rates in the well were followed both by means of steel coupons and by analysis of the produced water for iron. Stick corrosion preventive was lubricated into the tubing daily, and the well was shut in for 15 minutes to allow the stick to fall and melt. The solid inhibitor used was in the form of cylinders 1.5 in. in diameter by 18 in. long, weighing approximately one pound.

These results show that after the corrosion preventive sticks were employed, the corrosion rate was reduced by 99.5 percent as judged by well-head coupons and by 98.2 percent as judged by iron content of the water.

The successful use of organic inhibitors in oil and gas wells has encouraged experimentation on the application of these reagents for the solution of other corrosion problems in the petroleum industry. Table II shows the results obtained in a sour gas distributing system before and during treatment with an organic inhibitor. This system handles approximately 10 Mmcf of gas per day, compressed to service approximately 150 gas lift wells. A 25 percent solution of organic inhibitor in kerosine was pumped continuously into the compressor discharge through a diesel injector nozzle. Steel test coupons were placed in the gas line at a branch 1.6 miles from the compressor, and at the end of one branch 3.6 miles from the compressor. It will be noted that after about 4 months of treatment the corrosion rate at the end of the line had been reduced by about 99 percent.

Table III presents the results obtained by introducing corrosion inhibitor into the reflux stream of a gasoline plant stripping column. The tower top temperature was about 220° F. The top trays and column walls experienced severe attack before treatment. The corrosion rate was followed by daily analysis of the water trapped in the two top trays. The average iron content values for the periods shown are given in the table.

It is to be noted that the iron content of the condensed water actually increased during the first month of treatment, a phenomenon which is often noted in the treatment of oil and gas wells when regular water analyses for iron content are carried out. The explanation for this effect is not known, but it seems likely that it results from loosening of old corrosion products by the inhibitor.

Organic corrosion inhibitors are also finding application in the protection of water disposal wells and water injection wells used for secondary recovery. Table IV presents results typical of those obtained

in the treatment of flood waters used in secondary recovery. In this case, inhibitor was added down the casing of the water supply well, and corrosion rates were followed by exposing steel coupons to the water stream at the supply well-head, in the reserve tank and at two input wells. The water system was closed, and received no other treatment except the addition of polyphosphate. More than a 95 percent reduction in corrosion rate was obtained by the use of about 10 ppm of inhibitor in the water.

It has been found that when organic inhibitors are used, even in insufficient amounts to eliminate corrosion almost entirely, the residual corrosion is generally quite uniform in nature. Pitting action is thus eliminated at low inhibitor concentrations.

Mechanism of Organic Inhibitor Action

Largely as the result of the studies of Evans and co-workers, corrosion inhibitors, both inorganic and organic, have come to be classified as either anodic or cathodic, depending upon whether they function by blocking the reaction at the anode or at the cathode of the electrolytic cell involved in the corrosion process. Some reagents are known to be capable of inhibiting both anodic and cathodic reactions.

The relatively high molecular weight, semi-polar inhibitors of the types used to give the results such as described above are believed to function by adsorption on metal surfaces to give well organized surface films. Whether such films are preferentially adsorbed at particular spots on the metal surface, such as at local anodes or cathodes of a corrosion cell, has not been clearly established. Also, the nature of the forces responsible for adsorption are not clearly determined.

Hackerman and co-workers,¹³ as the result of electron diffraction and other studies of films of adsorbed

TABLE III
History of Corrosion in Gasoline Plant Stripping Column
Corrosion Inhibitor Introduced into Reflux Stream

Test Period	Volume Ratio Reflux/ Inhibitor	Iron Content of Water from Top Trays, PPM
Before Treatment.....		160
October 3 to November 1, 1949.....	46,600	175
November 1 to January 1, 1950.....	51,100	20
January 1 to February 1.....	55,600	13
February 1 to March 1.....	67,200	15
March 1 to April 1.....	62,000	6.5
April 1 to May 1.....	60,000	4.5

TABLE IV
History of Corrosion in Water Flood System
Corrosion Inhibitor Introduced Down Casing Annulus
of Water Supply Well

Test Period	Volume Ratio Water/ Inhibitor	Corrosion Rates, Mills per Year			
		Supply Well- Head	Re- serve Tank	Input Well No. 1	Input Well No. 2
May 27 to June 12, 1950.....	*	18.2	13.3	9.6	10.4
June 12 to July 15.....	*	26.7	11.6	9.0	10.7
Sept. 12 to Sept. 26.....	88,200	1.1	1.8	1.0	0.79
Oct. 11 to Oct. 24.....	101,500	0.55	**	0.57	0.63
Oct. 24 to Nov. 14.....	101,500	0.58	**	0.37	0.37

* No inhibitor used.

** Not determined.

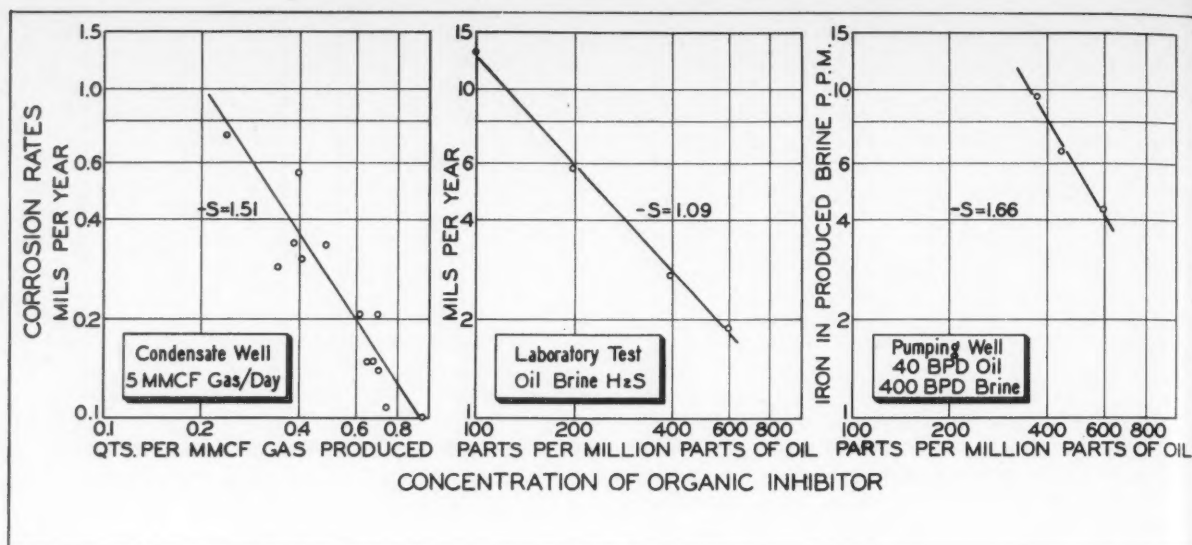


Figure 6—Log-log graph of corrosion rate versus inhibitor concentration for three different corroding systems.

inhibitors on steel surfaces, conclude that at least some compounds undergo general adsorption on the metal surface with considerable orientation and structure and, further, that the adsorption is not completely reversible.

If it is assumed that the surface metal atoms covered by adsorbed inhibitor molecules are incapable of reacting with the corrosive medium, and that the uncovered surface corrodes at its normal rate, it might be expected corrosion rate could be related to inhibitor concentration through a consideration of the adsorption isotherm for the inhibitor. According to Langmuir's theory of adsorption with a saturation limit, the relation between the fraction, F , of surface covered by an adsorbed film and the concentration, C , of solute, is given by

$$aC(1 - F) = bF$$

where a and b are constants for a given surface and solute.

Where the surface is nearly saturated, which, by the assumption above would be a required condition for a low corrosion rate, the fraction F is nearly unity and variations in this quantity become negligible compared to variations in $(1 - F)$, the fraction of surface not covered by adsorbate.

Thus,

$$(1 - F) = \frac{b}{aC}$$

at high degrees of adsorption. If the corrosion rate is proportional to the free metal surface available for contact with corrosive medium, it may be put,

$$R = k(1 - F) = \frac{kb}{aC}$$

where R is the corrosion rate and k is a constant of proportionality.

Letting K represent the combined constants, then

$$R = K/C \quad (1)$$

from which it follows that

$$\frac{dR}{d(1/C)} = K$$

or,

$$\frac{d \log R}{d \log C} = -1 \quad (2)$$

Figure 6 presents the graph of log of corrosion rate versus log of concentration for three different corroding systems. The gas condensate well data are those shown in the well history of Figure 5, taking the last six months of uninterrupted inhibitor treatment. The pumping well corrosion rates were obtained in a California well and represent average iron content values over periods of at least 45 days at each inhibitor concentration. The laboratory data were obtained by rotating steel coupons for three days in naphtha and brine under 0.25 atmosphere of hydrogen sulfide. The liquid phase contained the same inhibitor as that used in the two wells.

It is to be noted that in all three cases the data fall reasonably close to a straight line, but only in the laboratory test was the slope of the line nearly -1 , the value predicted by Equation 2. In the other cases the corrosion rates diminished more rapidly with increasing inhibitor concentration than would be predicted by Equation 2, although the linear log-log relation was maintained.

The departure of the laboratory results from those obtained in the field may be due to the shorter exposure time. If considerable time is required for the inhibitor film to form and reach equilibrium with the solution, a substantial amount of the total corrosion may occur during this interval, when the test period is short.

The slope of the log-log plot of corrosion rate versus inhibitor concentration, as found with the well data, suggests that these variables are related by an equation similar to Equation 1, but in which the solute concentration is raised to a power greater than

one. Expressed formally, the apparent dependence of corrosion rate on concentration may be written.

$$R = K/C^n$$

where K is a constant for a given system and n has a value of about 1.6.

Further experiments to determine corrosion rates over a wide range of inhibitor concentrations, and, preferably, at several different temperatures, would be helpful in defining more clearly the kinetics of inhibitor action.*

The fact that the corrosion rate appears to be somewhat less than predicted from a simple absorption theory is not too surprising. Surface films of high molecular weight substances on metal, besides covering part of the surface, may be expected to decrease the rate of transfer of ions or molecules to and from the uncovered surface. The mechanism of such behavior may be pictured as similar to the action of surface films in lowering the evaporation rate of water. Langmuir and Schaefer¹⁴ found that surface films of fatty acids, even at relatively low pressures, presented a substantial energy barrier to penetrating molecules. Similarly, the slow attainment of surface tension equilibrium of solutions of surface active materials appears to be explained by the presence of an energy barrier opposing penetration of the surface film formed by early arriving molecules on the surface.¹⁵

These effects apparently arise from lateral forces between molecules of a monolayer film. Penetration of the film by migration of a foreign molecule results in dislocation of oriented molecules composing the film and is opposed by the forces which give structure and regularity to the adsorbed layer.

Similarly, in the case of adsorbed layer on a metal,

* The corrosion rate-concentration dependence presented above augurs strongly against the theory that inhibitor adsorption takes place at local cathodes or anodes as the result of purely electrostatic forces acting on an ionizable compound. Where such forces are solely responsible for adsorption, the relation between concentration of adsorbate on the surface and in solution is given by the Boltzmann distribution (see N. K. Adam, "Physics and Chemistry of Surfaces," Oxford Press, 3rd. Ed., 1941, p. 357):

$$\frac{C_{\text{surface}}}{C} = e^{eP/DKT}$$

where Z is the ion charge, P is the electrokinetic potential, D is the dielectric constant of the solution, k is Boltzmann's constant and T is the temperature.

For a given system, the exponent of e is a constant, and the fraction of charged surface covered by adsorbate is directly proportional to surface concentration of adsorbate. Thus

$$F = KC$$

where K is a constant.

If corrosion rate is directly related to the fraction of charged surface not covered by adsorbed inhibitor ions it follows that

$$R = K_1 - K_2 C$$

where K_1 and K_2 are new constants.

From this relation it is seen that corrosion rate should decrease linearly with increasing inhibitor concentration, since

$$\frac{dR}{dC} = -K_2$$

a result which is not supported by the available data.

it may be expected penetration of the layer by the corrosive medium will be opposed by an energy barrier even when the surface is only partially covered, such barrier increasing rapidly as the adsorbed film becomes more closely packed and more highly organized in structure. Thus, may be described qualitatively the added effect of inhibitor concentration beyond that predicted from area considerations alone.

Conclusions

The results of several years experience have clearly established the fact that properly selected and applied semi-polar, organic inhibitors are capable of greatly reducing corrosion in oil wells, gas wells and many other installations handling petroleum and natural brines. The action of such inhibitors appears to result from surface adsorption which inactivates a portion of the metal and imposes a barrier to migration of the corrosion medium to the metal surface. Further experimentation and application of organic corrosion inhibitors will be required to define clearly their limits of use and the detailed kinetics of their behavior.

Acknowledgment

I am indebted to Dr. W. F. Gross, Mr. G. E. Purdy, and Mr. L. T. Monson for compilation of much of the data presented herein. The assistance of the Southern Union Gas Co., the Continental Oil Co., and many other oil and gas producers is also gratefully acknowledged.

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Corrosion of Railroad Hopper Car Body Sheets*

By B. J. KELLY*

THE ANNUAL LOSS from corrosion of iron and steel in the United States has been variously estimated at values ranging from \$100 million to about \$1½ billion. The loss is tremendous, whichever estimate is accepted as the correct one.

A considerable part of this annual expense is borne by the railroads because of the corrosion of buildings, bridges, track and signal equipment, and rolling stock. Each of these types of equipment suffers sufficiently great loss from corrosion that all should be given consideration, but the operating conditions for each type are different and are so important from the standpoint of corrosion that each type of equipment must be considered separately. The present discussion deals specifically with one of the more frequently replaced structures, the hopper car body.

The service life of the body sheets in steel hopper cars is dependent upon several factors, among which are mechanical abuse, abrasion and corrosion, not to mention collisions and damage from the increasing use of car shakeouts. Two of these factors, abrasion and corrosion, are closely allied in shortening the lives of hopper car bodies.

The extent of damage to body sheets by abrasion depends upon three things: 1) the character of the lading, 2) the frequency of unloading, and 3) the hardness or tensile strength of the sheet material. Hard, sharp lading is more abrasive than more rounded, softer lading; the more frequently a car is unloaded, the more often the surfaces of the sheets are subjected to wear; and it has been found that, in general, sheets which are harder or have a higher tensile strength are more resistant to abrasion than softer sheets. Abrasion also plays a part in the corrosion of steel body sheets by removing the protective oxides which form on the surfaces of some grades of steel.

The extent of damage to body sheets by corrosion is dependent upon the character of the lading, the atmospheric conditions to which the car is subjected, the design of the car, and the composition of the body sheets. The character of the lading is important in that it controls the amounts and types of chemicals which come in contact with the sheets and the amount of moisture retained in the car. The important atmospheric conditions include the type of atmosphere in which the car is generally operated and the amount of rainfall encountered. The car design is vital because it generally establishes the amount of localized corrosion in a car, and it is the localized corrosion which results in most of the corrosion fail-

Abstract

The corrosion of railroad hopper car body sheets is dependent upon the character of the lading, the atmospheric conditions to which the car is subjected, the design of the car, and the composition of the body sheets. Information obtained from a large number of tests of various materials exposed in different kinds of atmospheres has been correlated with data obtained from service tests of a few of these materials in railroad hopper cars. On the basis of assigned ratings of 1 for carbon steel, it has been found that copper steel has an atmospheric corrosion resistance rating of 2 and a performance rating of 1½ to 1¾ in general service. A C-Mn-Cu Steel which also has an atmospheric corrosion resistance rating of 2, and a strength level somewhat higher than that of copper steel, is slightly superior to copper steel in hopper car service. The service performance of a high strength steel which has an atmospheric corrosion resistance rating of 5+ and a strength level equal to that of the C-Mn-Cu Steel, is considerably better than that of copper steel. Examination of hopper car bodies constructed of carbon steel, copper steel and high strength steels has shown that failures in the sheets generally occur in areas where lap joints or ledges permit accumulation of moisture, dirt and fines, and in areas adjacent to stiffening members. The results of these investigations indicate that in order to obtain the maximum service from materials used for hopper car bodies, the design of the car must be considered simultaneously with the composition of the sheet material.

ures in the body sheets of hopper cars. The composition of the steel used for the body sheets is obviously of importance, since the resistance to corrosion is largely dependent upon composition.

Some of the factors mentioned above are not subject to control by the railroads—such as the type of lading, frequently of unloading, and the atmospheric conditions. The design of the car and the material of construction can be selected by the railroads and are, therefore, the controllable factors involved in the corrosion of hopper car sheets.

With respect to the corrosion resistance of the various grades of steel used for hopper car construction, a great deal of information has been obtained from corrosion tests conducted in different types of atmospheres. These corrosion tests have shown the effects of various alloying elements on the atmospheric corrosion resistance of steel and also have made possible comparisons between different grades of steel. From such tests, it has been established that the loss in weight of copper steel in the different atmospheres is about one-half that of the average of a wide range of carbon steel compositions. Copper steel has, therefore, been assigned an atmospheric corrosion resistance rating of 2, and thus carbon steel has a rating of 1. These figures mean that if a hopper car body were built with copper steel in one end and carbon steel in the other end, the copper steel sheets would rust away about one-half as fast

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as the carbon steel sheets, provided that the car was exposed only to atmospheric corrosion and that some design feature did not complicate the corrosion picture. Such conditions are never met in hopper car service—in the first place, hopper cars are made to carry lading, and the corrosive conditions encountered with lading are not the same as those encountered at atmospheric exposure. In the second place, design features do enter the picture and affect the rates of corrosion of the materials. Thus, the values of 2 for copper steel and 1 for carbon steel can only be interpreted as an *indication* that copper steel will perform better than carbon steel in actual service in hopper cars.

This expected improvement by the use of copper steel was verified in a service test reported by Dr. J. S. Unger¹ in 1928. One hundred hopper cars and one hundred gondola cars were built with copper steel and carbon steel in opposite halves of each car. The cars were put in service for 13 years hauling coal and iron ore on the Bessemer and Lake Erie Railroad and were then dismantled. Typical results obtained from measurements of the weights of the sheets are shown in Table 1.

This work indicated that, although the atmospheric corrosion resistance rating of copper steel is 2 times that of carbon steel, the service performance rating of copper steel was only $1\frac{1}{3}$ to $1\frac{1}{2}$ times that of carbon steel. Other experience has since proved that this service performance rating is generally correct.

Extensive atmospheric corrosion tests have also been made with the steel compositions which are classified as High-Strength, Low-Alloy Steels or, as they are generally called, the High Strength Steels. The results obtained from such tests show that, with copper steel rated as 2, a grade which we shall call Carbon-Manganese-Copper (C-Mn-Cu)* Steel has a rating of 2 and USS Cor-Ten has a rating of 5+.

Experience with carbon steel and copper steel sheets in hopper cars indicates that, based on the above comparative atmospheric corrosion resistance ratings, the service performance of C-Mn-Cu steel would be equal to that of copper steel. On the same basis, the service performance of Cor-Ten would be markedly better than that of either copper steel or C-Mn-Cu steel. Consideration, however, of the fact that abrasion resistance is a factor in the life of body sheets of hopper cars, leads to the expectation that C-Mn-Cu steel would be slightly superior to copper steel and that the higher abrasion resistance of Cor-Ten would also be reflected in its service performance.

In order to get actual service performance data on these three grades of steel, the author's company arranged to have thirteen 50-ton hopper cars rebuilt in such a way that one-half of each car body was con-

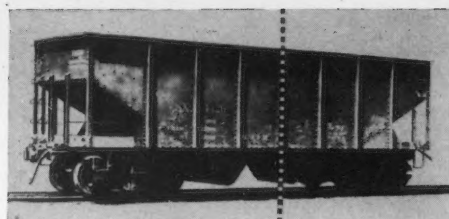


Figure 1. View of experimental hopper car rebuilt for Carnegie-Illinois Steel Corporation.

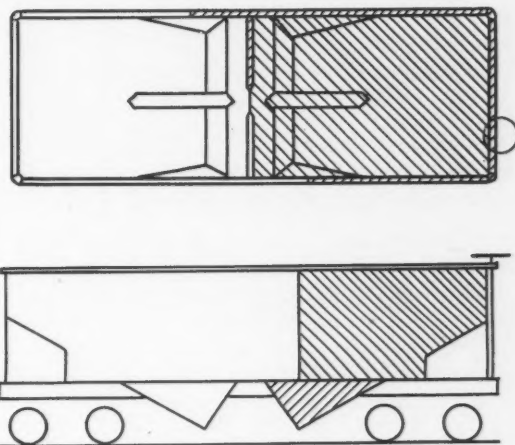


Figure 2. Schematic diagram of experimental car showing placement of different materials.

structed of one of the three test materials, and the other half of each body of another of the test materials. The weight of each sheet was determined and the thicknesses were measured at various locations before the sheets were installed on the cars. Figures 1 and 2 show views of the cars, which were placed in service in November 1934.

Coke Hauling Service

Eight of these cars were restricted to coke hauling service between a coke plant and a blast furnace plant. A record kept during the first six months of operation indicated that each car made an average of slightly more than 12 trips per month. The tremendous increases in freight tonnages during the years subsequent to 1938 resulted in the test being discontinued.

Finally, in December 1944, the cars were shopped

TABLE I
Weight Losses of Hopper Car Sheets
After 13 Years in General Service

PART	Original Weight, Lbs.	% Loss in Weight	
		Carbon Steel	Copper Steel
Center Floor Sheet.....	145	47	36
Side Floor Sheets.....	1331	40	27
Cross Hood and Diaphragm.....	797	47	36
Inside Hopper Sheets.....	257	46	37
Outside Hopper Sheets.....	325	50	29
Intermediate Side Sheets.....	517	49	9

*Analyses of Steels Used Were:

	C	Mn	P	S	Si	Cu	Cr
USS Cor-Ten.....	0.08	0.23	0.144	0.021	0.82	0.39	1.01
C-Mn-Cu Steel.....	0.24	1.40	0.019	0.022	0.20	0.28	.....
Copper Steel.....	0.13	0.50	0.021	0.036	.....	0.28	.....

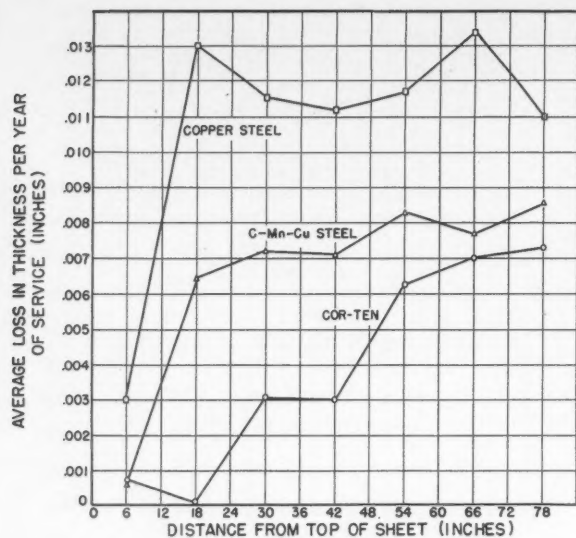


Figure 3. Losses in thickness at different locations on copper steel, C-Mn-Cu Steel and Cor-Ten intermediate side sheets in coke-hauling service.

for major repairs and it was decided, in view of the condition of the underframe members and trucks, that the cars should be scrapped. Most of the floor sheets had been replaced or had been patched too much to be of any value for the test but a number of the other sheets were in fairly good condition. Consequently, when the cars were dismantled, representative sheets were chosen from which reliable data concerning the performances of the test materials could be obtained. These sheets were cleaned in a solution of caustic soda, and pickled in a sodium hydride bath. The sheets were weighed to the nearest ounce. The results obtained from this investigation are shown in Table II.

TABLE II
Weight Losses of Hopper Car Sheets
After 10 Years in Coke Service

PART	Average Loss in Weight Per Year of Service, Lbs.		
	Copper Steel	C-Mn-Cu Steel	Cor-Ten
Slope Sheets.....	17.6	15.6	24.7
Cross Ridge Sheets.....	3.4	2.6	12.4
Inside Hopper Sheets.....	6.6	5.1	2.0
Outside Hopper Sheets.....	18.1	15.0	4.1
Center Side Sheets.....	19.5	15.3	8.0
End Sheets.....	3.7	2.1	1.0

TABLE III
Weight Losses of Hopper Car Sheets
After 11 to 13½ Years in Coal Service

PART	Average Loss in Weight Per Year of Service, Lbs.		
	Copper Steel	C-Mn-Cu Steel	Cor-Ten
Side Slope Sheets.....	18.5	16.2	8.6
Cross Ridge Sheets.....	7.0	7.4	3.7
Inside Hopper Sheets.....	2.5	2.4	1.6
Outside Hopper Sheets.....	3.6	3.3	1.8
Center Side Sheets.....	6.7	5.4	3.4
Intermediate Side Sheets.....	9.1	5.7	2.1
End Sheets.....	1.4	1.1	0.7

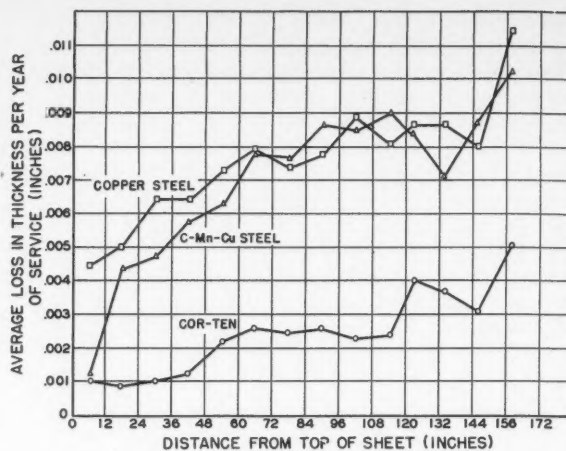


Figure 4. Losses in thickness at different locations on copper steel, C-Mn-Cu Steel and Cor-Ten slope sheets in coal-hauling service.

None of the slope sheets made of copper steel or of C-Mn-Cu Steel were available for comparison with the Cor-Ten slope sheets, but these losses should be in the same proportions as the losses of the cross ridge sheets. It should also be noted that in the cross ridge sheets, where *abrasion* is the major factor involved in the weight losses, the copper steel lost about 1½ times as much as the Cor-Ten, and the C-Mn-Cu Steel about 1¼ times as much as the Cor-Ten. In the side and end sheets, where *corrosion* played a more important role, the copper steel lost more than twice as much weight as the Cor-Ten, and the C-Mn-Cu Steel lost nearly twice as much weight as the Cor-Ten.

These data show that use of the more corrosion resistant grades of steel results in a general improvement in the performance of hopper car body sheets. Failures in body sheets, however, generally occur at localized areas, usually in the lower parts of the cars, which are subject to more abrasion and corrosion. Measurements of losses of weight reflect only an over-all condition and do not indicate the severity of localized losses. In order to obtain information of this nature, the thicknesses of some of the sheets from these coke cars were measured at various spots with a micrometer. Figure 3 shows the losses in thickness of the intermediate side sheets. The losses increased fairly uniformly from top to bottom except for copper steel. At the worst spot, the copper steel lost 13.4 mils per year, the C-Mn-Cu Steel 8.6 mils per year and the Cor-Ten 7.3 mils per year. (A mil is 0.001-inch.)

Coal Hauling Service

The other five cars of the lot of 13 experimental cars were assigned to coal hauling service between a bituminous coal mine and one of the plants of the United States Steel Company. Records indicate that during the first six months of operation, these cars hauled an average of slightly over three loads per month. Two of these cars were retired from service in December 1945, after 11 years of service. The floor sheets of the third car became perforated and were replaced in July 1948, after 13½ years of service. The

third, fourth and fifth cars were retired from service on May 1, 1950, after 15½ years of service. These last three cars have been dismantled but the results from examination of the original test sheets were not available when this manuscript was submitted.

The sheets removed from the coal cars were examined in the same way as those removed from the coke cars. The losses in weight of the various sheets of each material are shown in Table III. The losses for all three materials are considerably lower in the coal cars than they were in the coke cars. A decrease in the severity of the abrasion resulted in an improvement in the performance of all three materials, but the improvement in the performance of Cor-Ten is considerably greater than that of the other steels. Apparently, resistance to corrosion is a much more important factor in the performance of hopper car sheets in coal service than in coke service.

Thickness measurements were also made on the sheets removed from the coal cars to determine the amount of localized loss in thickness. Figure 4 shows the losses per year of service of the slope sheets. These measurements verified the indications shown by the weight loss measurements. The losses in thickness of the copper steel and of the C-Mn-Cu Steel sheets were approximately equal and were considerably higher than those of the Cor-Ten sheets. The maximum losses in thickness per year of service occurred near the bottoms of the sheets and amounted to 11.5 mils for copper steel, 10.2 mils for C-Mn-Cu Steel and 5.1 mils for Cor-Ten. The appearance of the bottom parts of the slope sheets removed from the car which was in service for 13½ years is shown in Figure 5. Both these sheets, one of which is copper steel and one of which is C-Mn-Cu Steel, were originally ¼-inch thick and both failed to about the same extent, indicating that, as shown by the previous figure, these materials were about equal in performance. Figure 6 shows the lower parts

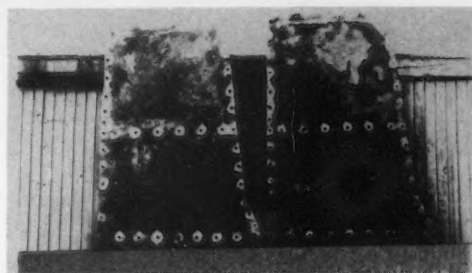


Figure 5. View of lower portions of slope sheets after 13½ years of coal-hauling service. Both sheets were originally ¼-inch thick. Copper steel sheet at left and C-Mn-Cu Steel sheet at right.

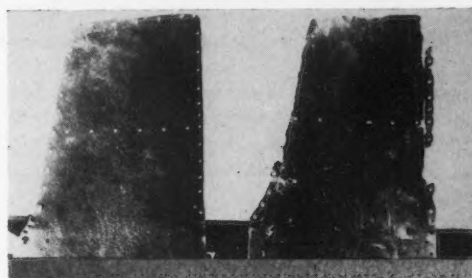


Figure 6. View of lower portions of slope sheets after 11 years of coal-hauling service. Both sheets were originally 3/16-inch thick. Cor-Ten sheet at left and C-Mn-Cu Steel sheet at right.

TABLE IV
Weight Losses of Hopper Car Sheets
After 13 Years in General Service

PART	Average Loss in Weight Per Year of Service, Lbs.	
	Copper Steel	Cor-Ten
Slope Sheets.....	17.6	9.3
Cross Ridge Sheets.....	10.6	5.5
Inside Hopper Sheets.....	3.0	2.1
Outside Hopper Sheets.....	5.2	2.4
Center Side Sheets.....	8.2	3.0
Intermediate Side Sheets.....	8.3	2.9
End Sheets.....	2.3	0.4

TABLE V
Comparison of Various Materials in Service in Hopper Cars

Maximum Average Losses in Thickness per Year of Service, in Mils.							
Type of Service	R.R.	Intermediate Side Sheets			Slope Sheets		
		Cu Steel	C-Mn-Cu Steel	Cor-Ten	Cu Steel	C-Mn-Cu Steel	Cor-Ten
Coke....	A	13.4	8.6	7.3	....	....	14.1
Coal....	B	5.8	4.6	0.5	11.5	10.2	5.1
General..	C	6.2	....	2.5	9.4	....	6.4
	C	....	....	2.9	....	....	6.2
	D	....	....	2.2	....	....	5.3
	D	....	....	2.4	....	....	5.3
	E	....	....	1.5	....	....	5.9

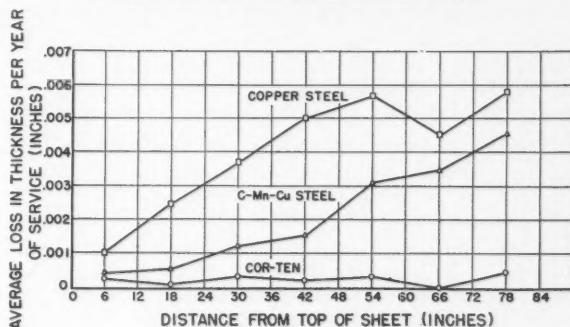


Figure 7. Losses in thickness at different locations on copper steel, C-Mn-Cu Steel and Cor-Ten intermediate side sheets in coal-hauling service.

of the slope sheets removed from one of the cars which was in service for 11 years. These sheets were originally 3/16-inch thick. The sheet on the left, which is Cor-Ten, is in good condition, while the C-Mn-Cu Steel sheet on the right has failed all around the chute. This performance indicates, as shown in Figure 4, that copper steel and C-Mn-Cu Steel were about equal in performance and that Cor-Ten was superior to both.

Thickness measurements were also made on the intermediate side sheets removed from these cars. The results obtained are shown in Figure 7 and indicate, as did the weight loss measurements, that Cor-Ten lost considerably less than the other two materials.

General Service

One of the Eastern railroads had a similar experience with some experimental 50-ton hopper cars



Figure 8. Typical locations of corrosion failures in hopper car side sheets.

which were rebuilt in 1935. The test included six cars, but three of them were lost due to collisions and other mishaps. The remaining three cars were in general service hauling bituminous coal, limestone and iron ore for 13 years. One of the test cars had Cor-Ten sheets in both ends, and the other two cars had copper steel sheets in one end and Cor-Ten sheets in the other end. When the cars were dismantled, the sheets were cleaned and weighed and the losses in weight were calculated. These results (Table IV) show that in the floors, Cor-Ten lost a little more than one-half as much weight as the copper steel, and that in the sides and ends Cor-Ten lost considerably less than one-half as much as the copper steel. The thicknesses of the sheets removed from these cars were also measured and the results obtained were similar to those described above. The maximum average annual losses on the slope sheets were 6.4 mils for the Cor-Ten and 9.4 mils for the copper steel, and on the intermediate side sheets were 2.5 mils for Cor-Ten and 6.2 mils for copper steel.

The data obtained from measurements of the thicknesses of the sheets removed from the three groups of cars discussed above, as well as from four other groups of cars are summarized in Table V. The results obtained from these measurements show that, for the types of service encountered by these cars, the steels with higher strength are superior to copper steel and that the high strength steel with the better atmospheric corrosion resistance is considerably better than the other materials.

Corrosion and Car Design

High strength steels have been used in the construction of a large number of hopper cars in the last fifteen years—and in most of these cars, the thicknesses specified for the body sheets were reduced in order to decrease the weights of the cars. The lightweight cars were, in general, of the same design as the carbon steel and copper steel cars which were built during that time. After the cars had been in service for a number of years, it was found that the failures in the lightweight bodies were in exactly the same locations as the failures in the carbon steel and copper steel bodies. Most of the corrosion failures in the floor sheets occurred at the bottoms of the hopper chutes, at the ends of the

longitudinal hoods, adjacent to the body bolster support and behind vertical stakes—in other words, adjacent to areas which were stiffened by other members and in areas where lap joints or ledges permitted accumulation of moisture, dirt and fines. Corrosion failures in the side sheets also generally occurred in areas adjacent to stiffeners and ledges; along the side sill angles and up along the joint with the floor sheets, as shown in Figure 8.

Corrosion tests have shown that the superior atmospheric resistance of steels such as Cor-Ten is not developed in damp railroad tunnels and in other sites where the material does not have an opportunity to become dry periodically. The accumulation of dirt and fines at laps and ledges remains moist a greater part of the time and under these conditions the rates of corrosion of carbon steel, copper steel and Cor-Ten are not too dissimilar, and all three materials corrode somewhat rapidly.

There also appears to be another factor involved in the failure of hopper car body sheets in areas along ledges and adjacent to other stiffeners. During investigations of hopper car sheets, it was noted that, in every case of corrosion failure, the remaining sheet thickness increased sharply for a distance of two to three inches from the failure and then increased gradually to the top of the sheet. The sheet had corroded in the expected manner all the way from the top to within two or three inches from the failure, then, in this short distance, the thickness had decreased sharply to zero. In many cases, the retention of moist dirt did not account for this sharp decrease. It was then noted that this effect was evident only on very thin sheets, either those which were thin when installed or those which had corroded considerably. This accelerated corrosion, which is sometimes called "Flexure Corrosion," has been attributed to the fact that the sheets flex about the point of stiffness and the thinner the sheet, the greater is the amount of flexing. There appears to be a critical sheet thickness for a given panel size below which the sheets flex often enough and far enough to noticeably accelerate the corrosion rates of these three grades of steel and probably of other materials as well. Above this thickness the sheets do not seem to be materially affected.

The results of these investigations indicate that, insofar as corrosion is concerned, a careful decision must be made regarding two factors in order to obtain satisfactory performance from hopper car bodies—the design of the car and the composition of the sheet material. In order to avoid accelerated corrosion from accumulations of moist dirt, a material which is highly resistant to this type of corrosion must be used—the high alloy steels like stainless would probably be effective—or the design of the car must be such that ledges and pockets are eliminated. In addition to these factors, the problem of flexure must be considered. The critical thickness, mentioned above, may be exceeded either by adding stiffeners so that the effective panel size is reduced, or by simply increasing the specified thicknesses of the sheets. The following example of a hypothetical side sheet may serve to illustrate this point. Assuming a

critical thickness of 3/32-inch for the panel size in question, and assuming that ten years of service are required of the sheets before they are reduced to this critical thickness, a sufficient thickness must be added to the critical thickness to allow for ten years of corrosion. The results obtained from investigations of various groups of hopper cars indicates that, for such type of service, the allowance for Cor-Ten would be 30 mils and for copper steel 60 mils. Thus, for this particular set of conditions a Cor-Ten sheet 1/8-inch thick would be equivalent to a copper steel sheet 5/32-inch thick—a reduction in thickness of twenty per cent.

From these studies, it is evident that the design of the car must be considered simultaneously with the composition of the sheet material. If the material is to be a high alloy steel such as stainless, the design must be such that full life is obtained from the sheets, otherwise the application is not economical. There is not much advantage in using a superior material and then not getting the benefit of this superiority because of weaknesses in design. In order to obtain the maximum benefit from the use of superior materials, the car must be designed so that this superiority is not lost at localized areas. Assuredly, a simple substitution of a more corrosion resistant material, such as Cor-Ten for copper steel, will result in an improvement in the performance of car bodies, but to obtain the complete benefits from the materials used, the design of the cars must be carefully considered.

Conclusions

In summation, the service tests described above lead to the following conclusions regarding the per-

formances of various grades of steel in general hopper car service.

1. Copper steel is superior to carbon steel.
2. A steel with higher strength than copper steel and with atmospheric corrosion resistance equal to that of copper steel is slightly superior to copper steel. This superiority is more marked in those types of service in which abrasion is more important than corrosion.
3. A steel with higher strength than copper steel, and with atmospheric corrosion resistance considerably better than that of copper steel, is markedly superior to copper steel. The superiority of a material of this type, such as Cor-Ten is evident in abrasive services such as coke hauling, but is considerably greater under conditions where corrosion is more important than abrasion. Such conditions are found in hauling bituminous coal and iron ore.
4. In a specific design of car in general service, indications are that Cor-Ten sheets would last 1½ to 2 times as long as copper steel sheets of the same thicknesses if accelerated attack at localized areas is prevented by elimination of the severely corrosive conditions which ordinarily obtain at laps and ledges.
5. To obtain the ultimate benefits from the use of high strength steels, or of any materials as a matter of fact, the car must be designed specifically for these materials.

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Cathodic Protection Technical Practices

BULLETIN III

Prepared by CORRELATING COMMITTEE ON CATHODIC PROTECTION

MARCH 10, 1951

Bulletin I of this series, entitled "Management Information on Cathodic Protection of Buried Metallic Structures Against Corrosion," was issued in February, 1948, and published in *Corrosion*, 4, No. 9 (1948) Sept. Bulletin II was issued in June, 1949, and Bulletin IV in May, 1949. Bulletins II and IV were published in *Corrosion*, 5, No. 9 (1949) Sept.

1. General

BULLETIN NO. I, "Management Information," prepared by this Committee, describes cathodic protection in non-technical terms. It indicates generally how this beneficial technique can be applied, and the nature of certain interference problems to be solved cooperatively. Bulletins No. II, "Notification Procedures," and IV, "Joint Cathodic Protection Systems," further discuss these problems and indicate procedures for their solution. This Bulletin, No. III, deals with their technical aspects, and prevalent good practices.

Corrosion of metal is an electrochemical action. Where metals are in contact with an electrolyte, they will corrode if electric current* flows from them into the electrolyte. Conversely, they will not corrode if the current flow is stopped or reversed in direction. A metallic structure in contact with soil is such a metal in an electrolyte. If a stray electric current flows from the structure into the soil, the metal will corrode by electrolytic action called "electrolysis." If the metal is corroded by "concentration-cell" action, i.e., by selective chemical attack on a single metal structure contacting non-homogeneous soil, such will generate a current that will flow from portions of the structure into the soil. This latter action occurs to some extent along all buried structures traversing adjacent soil beds of different chemical properties.

In either type of corrosion, the outward flow of current from metal into soil indicates that the metal surface is discharging positive ions and is therefore "anodic." Experience proves that the attendant cor-

EXPLANATORY NOTE: This is the last of a series of four bulletins on Cathodic Protection.

It is anticipated that the four bulletins will be consolidated into a "Final Report of the Correlating Committee on Cathodic Protection" to be published soon by the National Association of Corrosion Engineers (NACE), 919 Milam Bldg., Houston 2, Texas, for sale at nominal cost to all interested parties. Inquiries and orders should be directed to the NACE Central Office.

rosion, if electrolytic, can be mitigated or stopped most practically by channeling the return of current from the structure through metallic conductors leading toward the current source. If the corrosion is of the concentration-cell type, or due to any causes other than stray currents, it can be stopped or mitigated by 1) stopping the flow of current by completely insulating or "coating" the structure, or 2) reversing the direction of current flow to make the structure "cathodic." This latter technique is called "cathodic protection."

This bulletin describes briefly the fundamentals of the application of such cathodic protection, and the mitigation of any electrolytic corrosion that may be caused by stray current from cathodic protection systems. It is not intended to deal with the mitigation of electrolysis caused by stray currents from other sources.

In metropolitan areas where congested interlacings of various types of buried structure systems exist, the problems of the mitigation of both types of corrosion are too complex to be dealt with in a bulletin of this general nature. Many of them are described in the articles listed in the Bibliography appended and in the more extensive bibliography cited in last paragraph of this Bulletin III. The solution of such problems is best

handled by local "electrolysis" committees composed of engineers who represent the several structure owners concerned. A list of such committees is given in an Appendix of Bulletin II.

Cathodic protection of underground metal structures has been used for more than 20 years, and it is of proven merit, but the methods followed in its application are still being developed and differ in detail among individual engineers. Extensive correlations of experience aimed to harmonize such differences are being actively undertaken by Technical Practices Committees** of the National Association of Corrosion Engineers. Significant results should attend their work. This Bulletin is confined to a general presentation of technical practices now in use.

In applying cathodic protection, the following questions arise:

1. How much protective current is required?
2. Where should the current supply points be located?
3. What type of power supply is best suited to the particular job?
4. What kind of ground-bed should be used?
5. Are the protective currents likely to stray to other structures and cause interference, or electrolysis? If so, what is the best all-around solution of the problem?

These questions are dealt with in the following sections.

2. Current Required for Proper Cathodic Protection

In practice, cathodic protection of a buried metal structure against corrosion consists of forcing protective currents through the surrounding electrolyte, usually soil or water, into the structure to be

* Currents dealt with in this bulletin are "direct" or unidirectional.

** A list of such committees dealing with problems relating to cathodic protection is given in Appendix A.

protected in sufficient density to counteract and prevent any outward flow from the structure of stray currents or the natural currents which are always associated with the corrosion process. These applied protective counter-currents serve to maintain the structure surface in a cathodic state. To determine in a given case how much protective current is required for full protection, it would appear logical first to measure the densities of existing corrosion currents, and then to estimate the density of the protective current necessary to suppress them.

But such direct measurement of the corrosion currents is impracticable. The locations of corrosive spots are never accurately known in advance and, if they were, the work required to measure their individual currents would be prohibitive. Also, the first application of protective currents will alter local conditions so that the current density required initially to stop corrosion may be greater than that required later to maintain effective protection.

Thus corrosion engineers have developed more practical test methods and criteria aiming at:

1. A minimum of field testing consistent with reliability.
2. Suitable and adequate field testing equipment.
3. Test data of a type that can be readily interpreted in terms of protection.

Most engineers concur that the most practical method of determining protective current requirements is to apply such current to the structure on a trial basis, using portable power supplies and temporarily-installed anodes. The current flow can be adjusted until relatively simple field measurements indicate that cathodic protection has been established on the structure sufficient to prevent further corrosion. (Suitable power-supplies and anodes are discussed in following Sections 4 and 5).

The adequacy of protection is best determined by measuring the potential it establishes between the structure and the soil under various rates of current flow. Such potentials can be measured by use of a voltmeter or potentiometer equipped with insulated lead-wires, one attached to a soil-contact reference

electrode (or half-cell) and the other to suitable test leads or a sharp prod capable of making good electrical contact with the structure metal. The last condition is especially important, because many erroneous or misleading voltmeter reading may occur if an IR drop or galvanic voltage is caused by any mill scale, corrosion products or pipe-coating that may remain between the contact prod and the bare structure metal. When prodding soft metals, due care must be taken not to puncture them.

The voltmeter should have an internal resistance at least fifty times that of the remainder of the circuit, this to minimize circuit resistance errors to a practical degree. Some engineers prefer to use potentiometers because of their infinite resistance characteristics and reliability. For making the voltmeter contact to the soil, a suitable non-polarizing reference electrode (or half-cell) is used. For testing on steel or black-iron structures, generally a copper-sulphate half-cell is used. For testing on lead cable-sheaths, a lead-chloride half-cell may be used. Some cable engineers, however, prefer to use an electrode made of the same metal as the structure.

The structure-to-soil potentials thus indicated by the voltmeter will differ according to the condition of the structure under test and on the location and type of reference electrode used. However, potentials measured with one type of electrode can be expressed in terms of others by merely adding or subtracting known conversion factors. If the electrode used is reliable, its type has little bearing on the final answer. The half-cell electrodes are generally preferred because their potentials are more easily reproduced and are less affected by environmental factors.

Based on such potential measurements, certain widely-accepted practical criteria, indices or "yardsticks" of adequate cathodic protection have been developed. Using the half-cell reference electrodes, experience has shown that adequate protection of steel or black-iron pipes usually is obtained if their potential is reduced by the

protective current to measure about -0.85 volt with respect to a copper-sulphate half-cell in contact with the soil.* For galvanized pipe, a potential with respect to a copper-sulphate half-cell of about -1.10 volts is required for protection. Adequate protection of lead cable-sheaths usually is obtained if their potential is reduced by the protective current to about -0.05 with respect to a lead-chloride half-cell.

Discretion must be exercised in employing any general-purpose yard-stick, since higher potentials may be required in environments such as cinder-fills or where bacterial corrosion is present. Only further testing or experience can indicate when protection is obtained under such conditions. Caution must be exercised when applying the higher criteria for steel and black-iron structures in the vicinity of other underground metal structures—particularly in congested metropolitan areas.

Using a reference electrode made of the same material as the structure is not normal practice for tests on steel or black-iron structures. This is because errors can occur, due to polarization and local oxidation effects, which are difficult to detect—especially by one unaccustomed to the use of such electrodes; thus their use is not recommended. On the other hand, underground cable engineers usually prefer to use a piece of lead-cable-sheath for the reference electrode. Lead cable-sheaths are considered to be protected if their indicated potential to soil with such an electrode is slightly negative.

Protective current flowing from the soil to a structure causes potential gradients which depend on the electrode location, the soil resistance, and the amount of current flow. The reference electrode used for measurements along a well-coated

* Calculated counter-potentials required to stop corrosion of iron in several different common chemical solutions averages 0.283 volt, ranging from 0.272 to 0.291 volt. Laboratory tests have been in close agreement with these. The potential between iron or low carbon steel (0.15 carbon content or less) in a solution and a copper sulfate half-cell contacting this solution has been determined as 0.54 volt; thus the potentials required between the above metals and half-cell to secure protection equal to or exceeding the calculated protective voltage plus the half-cell voltage, viz. 0.812 to 0.831 . A minimum potential of 0.85 volt which allows a factor of safety is commonly accepted as sufficient to protect most iron or steel structures underground.

pipe line or cable can be located either over or near the structure without introducing appreciable error. For measurements along a *poorly-coated* or *bare* structure, some engineers prefer to locate the electrode a distance away from the structure equal to the depth of its burial. Others favor placing the electrode at a distance where further removal causes no change in potential readings. The positioning of such electrodes is best determined by experience and, in general, will vary with the types of climate and soils. A special method, called the "null method," has been devised which aims to minimize the errors of electrode positioning. Engineers seeking to use this alternative method can find it explained in corrosion literature.¹⁸

Another completely different method sometimes used is to calculate the amount of protective current required on the basis of establishing a minimum adequate current density over the entire structure. The density required for protection of steel or black-iron structures in soils varies widely and is affected by soil type, resistivity, moisture, aeration, etc. Densities considered adequate for protection of these structures range from 0.50 to 20.0 milliamperes per square foot depending on whether the soil is mild or highly corrosive.^{14, 15} Such calculations sometimes are used to check the results obtained by the potential test methods above described. Also, they may be used for estimating the size of power supply required for the potential test methods.

All of the above indices are used to determine when sufficient current has been applied. However, use of larger-than-necessary currents adversely affects the economy of an installation. Such a practice increases the first cost of power-supply equipment and anodes or ground-beds, as well as the annual costs of current and anode replacements. Also, it increases any undesirable effects the currents may have on neighboring structures.^{48a}

In using any of these indices of current adequacy, it must be borne in mind that they apply only to conditions desired on the structure to be protected. The satisfactory

protection of one structure may in fact definitely harm adjacent ones, particularly lead cable-sheaths adjacent to steel pipe lines.

3. Location of Current Supply Points

The locations at which protective current should be applied to a structure as well as the amount of current required, may be determined by use of portable power supplies connected between the structure and temporary anodes. Batteries or portable motor-generator sets can be used. The resistance to soil of temporarily-installed anodes is usually quite high, thus a relatively high voltage must be used to obtain currents large enough to produce reliable structure-to-soil potential readings. These readings should be taken along the structure at points progressively away from the power-supply connection, this to insure that the current is adequate—but not excessively so—to produce the desired minimum potential or potential change all along the structure.

Where a long line is to be protected, the data obtained from a single temporary power supply and anode may be used to estimate the effects of additional current sources at regular intervals along the line. In such estimations, it is assumed that the change in the structure-to-soil potential produced by the test current is directly proportional to it. Such is not always true, however, because the current collected per square foot of area is not directly proportional to the structure-to-earth potential; also, the continued passage of current to the structure increases its surface polarization and acts to extend the area of the structure effectively protected.

Depending on conditions, it may take only minutes, or it may take several weeks, for structure-to-soil potentials to become stable. Short-time tests are liable to indicate excessive current needs, and this must be taken into account in the final system design—largely on the basis of experience. In some cases, the temporary equipment can be left in operation long enough to establish stable conditions and thus

most accurately indicate the required current.

The choice of current supply locations depends to a large extent on the type of permanent power supply suited to the job. If a central-station power source is to be used, sacrifice of some engineering nicety may be warranted to reduce the cost of service-line extensions. Local soil conditions also may influence the choice. A low-resistance ground reduces the voltage required to circulate the protective current, and correspondingly reduces costs of installed equipment as well as the recurring power bills, thus it is important to provide suitable low-resistance ground-beds. Usually, earth with a low resistivity serves best for this purpose. Because some locations along a structure insure better grounds than elsewhere, this factor is coordinated with the others.

The locations of supply points affect the tendency of cathodic current to stray into near-by structures. It is obviously desirable to select locations that minimize adverse effects, which may not be confined to electrolysis. Care should be taken to avoid locations near railroad tracks employing signal systems that might be falsely operated by direct current entering the rails. The likelihood of any adverse effects should be determined by cooperative tests made with the engineers of the operator of the railroad or other structures involved.

4. Available Current Sources

Sources of direct current power considered most practical for cathodic protection are:

A. External Power Sources

1. Ac-dc rectifiers
2. Dc generators driven by various types of prime movers.

B. Galvanic Anodes

(Magnesium, Zinc or Aluminum)

Where large amounts of current per location are required, it is generally more economical to use external power sources, although in some cases the use of a large group of galvanic anodes may be preferable.

Service from ac power, if available, is preferred as a prime source

by these engineers. In some cases, private power lines have been built along a pipe line for the sole purpose of supplying a number of ac-dc rectifiers. Most of the rectifiers in use are the copper-oxide or selenium types, connected to 60-cycle ac power lines. Copper-oxide and selenium rectifiers differ in their characteristics, but both types are satisfactory for cathodic protection service. Both provide an efficient, low-cost and low-maintenance source of direct current. A comparatively few vacuum-tube rectifiers are in use, probably because they become efficient only at unnecessarily-high output voltages, and their current output is smaller than for the copper-oxide or selenium types of comparable dimensions. Where an alternating-current power supply is available, rectifiers are much more satisfactory than ac-dc motor-generator sets.

Where a substantial current is required and an alternating-current supply is not economically available, engine-driven generator sets may be used. Wind-driven generators, being dependent on the weather, have only a limited field of use, but their lack of reliability can to some extent be compensated for by the addition of storage batteries or galvanic anodes. There are a few successful installations of this kind.

Galvanic anodes are unique in that they are self-powered. Together with the structure and the soil, they create gigantic "dry-cells." They can produce efficiently only a few hundred milliamperes per anode, but on coated structures or on plant of limited extent, this may provide adequate protection. It is often practical to install galvanic anodes, singly or in groups, at frequent intervals along a long line, and thus obtain the condition that might be obtained by rectifier-type supplies at wider spacings. For galvanic anodes, magnesium and zinc are now favored by corrosion engineers. A new type of magnesium ribbon can be laid parallel to the line and thereby provide a continuously-distributed anode. Aluminum so far has not been extensively used or shown to have suitable characteristics for this work. The characteristics of all

three types are being studied by a committee of the National Association of Corrosion Engineers.⁵⁴

The most appropriate metal for, and disposition of, galvanic anodes for protection in any given case will depend upon the structure metal and the soil conditions. Other conditions being identical, the current output of a galvanic anode depends on the effective electromotive potential of the anode metal relative to that of the structure metal.

Open circuit potentials between properly-installed galvanic anodes and reference half-cells contacting adjacent soil are relatively constant, that of magnesium relative to copper-sulphate being about 1.50 volts and that of zinc to the same reference being about 1.0 volt. However, it is often impossible to accurately predict the effective potential of a galvanic anode relative to an undisturbed buried structure, for two reasons.

First—the theoretical relative potentials calculated from the values listed in "electromotive series" tables of handbooks are seldom realized when the two metals are placed in soil or water. Second—the innumerable and often wide variations of undisturbed structure surface and burial environment cause corresponding and unpredictable effects on these potentials. Thus only local experience or testing can determine with reasonable accuracy what effective open-circuit anode-to-structure potential may be realized in a particular installation.

5. Anodes and Ground-Beds

The design of a good ground for the current supply depends on soil conditions and the amount of protective current required.⁵⁶ The term "ground-bed" usually refers to a group of anodes interconnected and operated as a unit. The terms "anode" and "ground-bed" are used herein somewhat synonymously. In cathodic protection the corrosion is transferred in effect from the structure to the buried anode, thus the latter in time will be consumed and need to be replaced.

Where the soil resistivity is low and the current requirements small,

steel rods driven vertically into the earth can be used. Often junk iron or steel pipe or old rails are so used. These are consumed at a rapid rate, but, if easily replaced, may be more economical than a longer-lasting arrangement of greater cost. The use of finely-divided coke or "coke-breeze" surrounding the buried steel has been found, in some instances, to increase its life. Carbon and graphite rods also furnish suitable ground anodes. Some difficulty has been experienced in obtaining economical life from carbon rods in salt environments, but specially-treated graphite rods have been buried in salt-impregnated earth and directly in sea water with favorable results.

The physical size of the anode installation usually is designed to insure a reasonably long service life, and to provide a resistance low enough to minimize power requirements. For large installations where costs are substantial, an analysis comparing the annual costs of grounds of various resistances versus their power requirements will indicate the optimum combinations. Formulas for estimating the resistance to ground of various shapes, sizes and arrangements of ground electrodes are available.³⁹

The wires connecting the external power source and the anode or ground-bed will be corroded unless they are insulated along their length and at their connection to the anode or ground-bed. This is not the case with galvanic anodes, since the wire also is cathodically protected and need be only mechanically strong. However, insulating the wire will serve to prevent waste of protective current.

6. Cathodic Protection Coordination

Cathodic protection systems properly engineered with full cooperation between the owners of the protected and the adjacent structures should cause no damage to the latter. In fact, such cathodic installations frequently will provide a small measure of protection to the other structures. However, this ideal situation can be obtained only through such cooperation. Its need is discussed in Bulletin I, and it is implemented in Bulletin II which outlines procedures for the

notification of neighbors where cathodic protection is contemplated. Cathodic protection is an invaluable tool of industry for the mitigation of corrosion. Thus any arbitrary restriction of its use should be avoided because such restrictions would impair the over-all industry economy and retard the desirable wide-spread use of cathodic protection.

When cathodic protection is applied to a buried structure, some of the protective current will unavoidably stray through the soil to other near-by structures. After traversing these other structures, the current will return in some way to the protected structure. If, in this return circuit, the current leaves the unprotected structure through the surrounding soil or water, then that portion of the structure is made anodic and may corrode due to electrolytic action. Under some circumstances such stray-current interference may become serious.

As has been indicated in Bulletin II, the extent of the stray current problem depends in general upon three factors, which are A) the "influence" of the particular protection installation, B) the "susceptiveness" of the affected structure, and C) the "coupling" between the protected and affected structures. The first is to a large extent under the control of the designer of the cathodic system. The second and third are inherent in the structures and their environments, but an understanding of them will assist the designer of the cathodic protection installation to estimate the probable extent of the stray current and foresee what corrective measures may be needed to eliminate damage to other structures. These factors are discussed in more detail below:

A. Influence

"Influence," as herein used, is the inherent tendency of a cathodic protection installation to produce "stray currents." It depends upon the amount of current used, the location of the anodes or ground-beds, their configuration and resistance to earth, and the type of structure (ie, bare, poorly-coated or well-coated) being protected. For any fixed anode arrangement, and type of structure, and soil re-

sistivity, the influence is directly proportional to the current. This points up the costliness of using more current than necessary to achieve protection. To satisfactorily reduce undesirable effects on neighboring plant, it may be sometimes necessary to actually use less current than is needed for complete protection.

Most of the protective current enters a bare line relatively close to the anode. Thus the stray problem with protected bare lines is usually one of relatively high intensity over a limited area. A pipe line even poorly-coated requires much less current for protection than an uncoated one. With protected well-coated pipe lines the intensity may be lower, but the area of possible stray current effects may be greater. However, if a line is to be protected in place—or "as is"—there is no opportunity to alter the coating conditions.

A large current may be applied at one location with the objective of having it "reach out" to protect points some distance away. However, to minimize the influence, several smaller currents may be applied at intervals along the line to give more uniform coverage. For example, galvanic anodes supplying small currents at frequent intervals along a line are unlikely to create serious stray-current problems. Also, frequently the sum of these individual currents adequate for protection is smaller than the required "single-point" current.

The location of the anode or ground-bed with respect to the protected structure has a marked bearing on the influence, depending on whether or not the line is coated or bare. The closer the anode is to a protected bare structure, the smaller will be the influence, and vice versa. Also, as the distance between the anode and the protected bare structure is increased, the greater is the chance that nearby unprotected structures will be included in the circuit.

With coated lines, the distance to the anode is not so important, except as it affects the proximity of the anode to the unprotected structures. In general, the anode should be placed so as not to include an unprotected structure between it and the protected one, ie,

the protected structure should lie between an unprotected structure and the anode.

If two structures are more or less parallel, or if they cross and form some reasonably symmetrical arrangement, it is possible to so locate an anode for the structure to be protected that it will have a minimum effect on the other. In practice, however, such uniformity or symmetry is usually lacking; or the required location of the anode or ground-bed, when found, will be impractical for other reasons. However, every means of reducing the influence of an installation merits consideration.

B. Susceptiveness

"Susceptiveness," as herein used, is the inherent ability of an unprotected structure to pick up stray current and discharge it in a manner likely to cause corrosion. The most susceptible structure is an uncoated one, and the least susceptible is a structure with a highly-insulative coating. Between these extremes are pipe lines with leaky coatings and bare cables in tile or other semi-insulative conduits. A pipe line with a poor coating, as long as such coating is fairly uniform, is much less susceptible than a bare structure. Poor coatings do not prevent the pick-up and discharge of current, but they distribute it and reduce the chance of concentrated action. In view of the protection from stray currents as well as from natural corrosion to be afforded by coating, such should be considered on new structures to be laid in areas where cathodic protection systems are likely to be in operation.

C. Coupling

"Coupling," as herein used, is the change in potential of a particular unprotected structure when protective current is applied to a nearby structure. Assuming a constant influence and susceptiveness, the tendency of a cathodically-protected structure and its anode to cause the flow of current in a nearby structure depends upon the earth resistivity and the physical separation between the structures. The closer the spacing between the structures, the greater usually will be the current picked up and dis-

charged by the unprotected one. This is particularly true where lines cross near an anode, or where two paralleling lines have branches that cross.

For a given configuration of lines, the coupling increases with earth resistivity. However with relatively high earth resistivity—say over 10,000 ohm-cms or 100 meter-ohms—and resultant high coupling, certain favorable conditions result, viz—*a*) a relatively small current will establish protection of the one line, and *b*) the stray current is likely to leave the unprotected line over a wide area and thereby disperse its corrosive effect.

Where earth resistivity is low, the resultant coupling also is low, but the currents involved are likely to be large and to be picked up and discharged by the unprotected line within short distances and thus create a greater problem. Where lines are close together, such as under the same roadway, it appears that the most favorable condition is where the earth resistivity is high. For larger separations, the best condition is where the earth resistivity is low and the unprotected structure is far enough removed so that the coupling is small.

7. Mitigation of Effects Caused By Stray Cathodic Protection Currents

Pipe and cable systems suffer damage by electrolysis in some areas caused by strong stray currents leaking from dc-operated electric traction systems having a grounded return. Unless properly mitigated, this occurs where the current leaves the structures. However, those portions of the structure receiving the current from the soil are afforded varying degrees of cathodic protection. Where such grounded-return systems have been removed by transition to double-trolley and motor bus operation, the situation has changed in several respects.

Here the pipe and cable systems were relieved of the electrolysis, but they then suffered much more corrosion from other causes due to removal of the wide measure of cathodic protection previously provided by properly-mitigated stray rail currents. As a result, many

pipe and cable operators in those areas have had to install their own cathodic protection, and consequently are having to cooperate with others in new interference problems of their own making.

Street-railway electrolysis has been the object of cooperative study and mitigative effort since it was first recognized in about 1910. An inter-industry committee issued a classical report² on the subject in 1921. Although cathodic protection as a safeguard against soil corrosion is reported to have been used as early as 1922, its effectiveness was not generally recognized until 1933.^{4,5} The procedures today used to measure and stop cathodic-system interferences are much the same as those developed years ago to combat street-railway electrolysis. In metropolitan areas where subways, elevateds and some surface railway lines remain, the mitigation of stray-current electrolysis is still a major problem.

As before stated, when newly installing or replacing buried plant, consideration should be given to the use of coatings in areas where cathodic protection systems are likely to be in operation on adjacent structures. The more difficult problems generally arise in cases where existing plant is extensive and bare, and where cathodic protection is desired. Here the engineer has no opportunity to use coatings or to select routes that will avoid stray currents.

If several separately-owned structures are experiencing corrosion in the same area, every consideration should be given to the use of joint cathodic protection, as described in Bulletin IV. Where this is not practicable, the first duty of the operator installing cathodic protection should be to notify the owners of adjacent plant of his intention, as described in Bulletin II, and to enlist their cooperation in determining how best to avoid effects of stray currents.

For such cooperative effort, it seems impracticable to lay down general rules of procedure. From time to time cathodic protection will be used by many diverse owners of underground plant, and the job of investigating stray cathodic protection current effects will fall

first on one owner and then on another, thus it seems equitable for each owner to handle the testing work on his own plant. It also seems clear that each owner should be the judge of the protective requirements of his plant. This latter prerogative, while basic, should be exercised with sound engineering judgment and an avoidance of purely arbitrary decisions.

In general, the cathodic protection system should be designed with regard to limiting its "influence," as described above. In many cases, distributing the current along the protected structure and using the minimum current consistent with good performance will reduce the stray current to a negligible amount. Where this is not feasible, consideration should be given to the placing of resistance bonds between the protected and disturbed structures. The locations for these bonds will depend on circumstances.

Where the anode or ground-bed is close to the disturbed structure, stray current will generally be picked up in the adjacent sections, and discharged back to the protected line at more remote points. In this case, the most suitable location for interstructure bonds would seem to be at these discharge points. However, this may not be practicable. It may be better to select a more desirable location for the ground-bed or, if such is not possible, to restrict the current pick-up by properly-installed insulated joints. If the ground-bed is remote from the disturbed line, the stray currents may be collected at remote points and returned toward the power supply point where they are discharged into the soil. In this case, the best location for bonding usually is at the power supply point. In either case, the collection and discharge areas should be determined by test, since prediction of their location is impractical because of the many variables involved.

Where bonding offers a solution, the question of the total bond current required to provide satisfactory conditions must be answered. The operator installing the system will desire to keep this current at a minimum because of additional power cost. One gauge of the proper bond current is to drain

from the disturbed structure just enough current to reduce to zero the stray protective current discharged to earth. This is usually done by making most of the disturbed structure more cathodic than it was before the problem arose, so that it actually receives a slight degree of protection.

When the disturbed structure has a much higher resistance to ground than the protected structure, the bond currents are relatively small; thus low-resistance bonds can be placed without substantially increasing the total current requirements of the protected structure. Where this is not true, bonds of specific resistances must be used. These resistances can be estimated from test data, but their final values are best determined experimentally by adjusting the resistances of temporary bonds until the desired condition is obtained. To properly reflect only the changes produced by the stray protective current, the tests should be made with the cathodic protection system "off" and "on." Then only the changes produced by its operation should be considered. With proper bond installation and adjustment, the adverse effects of cathodic stray current should be eliminated.

8. Cathodic Protection Bibliography

The Correlating Committee on Cathodic Protection gave thought to including in this Bulletin some typical examples of cathodic system design and cathodic interference mitigation. However, in view of the almost infinite variety of structure configurations and conditions to be dealt with in practice, plus the need to keep this Bulletin of reasonable length, the text has been confined to the presentation of general principles.

Published literature contains many articles on the various phases of Cathodic Protection; in fact, a bibliography^{*11} prepared by Prof. F. A. Rohrman of the University of Colorado lists 436 such articles published prior to 1950. Many of these have been written by recognized leaders in the field, including individual members of this Correlating Committee. The official mag-

azine CORROSION of the National Association of Corrosion Engineers each month currently extracts nearly all recent articles on all phases of corrosion control. A number of representative articles are listed in Appendix B as a guide to the engineer who seeks further knowledge of cathodic system design and cathodic interference mitigation.

APPENDIX A

Technical Practices Committees of National Association of Corrosion Engineers Dealing with Problems Relating to Cathodic Protection

- TP-2 Galvanic Anodes for Cathodic Protection*
- TP-3 Anodes for use with Impressed Currents**
- TP-4 Minimum Current Requirements for Cathodic Protection
- TP-6 Protective Coatings
- TP-12 Effects of Electrical Grounding on Corrosion†
- TP-14 Instruments for Corrosion Measurements
- TP-16 Electrolysis and Corrosion of Cable Sheaths
- TP-17 Standardization of Procedures for Measuring Pipe Coating Conductance

* See item No. 55 of Bibliography for First Interim Report of this committee.

** See item No. 57 of Bibliography for First Interim Report of this committee.

† See item No. 53 of Bibliography for Report of this committee.

APPENDIX B

Selected Bibliography on Cathodic Protection

* Indicates published as a separate volume

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4. Development and Application of Practical Method of Electrical Protection for Pipe Lines Against Soil Corrosion. Starr Thayer. *API Proc.*, 14, 23, 1933.
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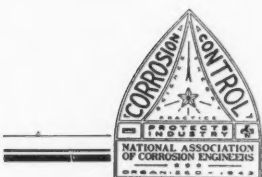
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Discussions

The Use of Cathodic Protection in Conjunction with Paint Coatings—A Progress Report. By W. L. Crosby. *Corrosion*, 6, No. 11, 383-388 (1950) Nov.

Comments by G. A. Works, Jr. Union Oil Co., Oleum, Cal.:

Mr. Crosby has set forth some interesting points that others have encountered in the problem of cathodically protecting submerged structures.

In practice, it would be generally impossible to secure a perfectly continuous paint film; and where discontinuities occur, the cathodic current densities produced by a galvanic system would be quite high. Peeling and failure of the adjacent paint film could then result from the mechanical action of the deposited calcareous coating or hydrogen gas discharged from the surface. Osborn¹ has reported no damage to the antifouling paint of a ship hull as a result of cathodic protection. Bernard and Christie,² however have found that severe stripping of the hull paint occurred when the current was not controlled. Somewhat better results were obtained where a controlled current density was employed.

In Table III, currents ranging from 22 to 83 milliamperes were measured during the first 77 days of the experiment. Since the major effect of these currents would be concentrated over the one square inch of paint free area on the panels, this would mean current densities in the order of 3000 to 12,000 ma/sq. ft. at the cathode surface. Densities of this order would be expected to deposit a coating consisting predominantly of magnesium. This is confirmed by the analysis shown in Table II. Humble³ has demonstrated the effect of current density on the com-

position of such coatings produced in sea water. Humble, Cox⁴ and others have also shown the protective nature of such coatings, and experimental data indicates that protection from corrosion continues for some time after the current has been stopped.

In my opinion, the author has demonstrated a completely practical solution to the problem. This would involve painting the transformer case to provide protection of a permanent nature over the un-submerged areas and temporary protection in the tidal range. Magnesium anodes would then supply current to protect cathodically the submerged areas. The paint coating would be expected to fail in the tidal zone, but it would be replaced by a calcareous deposit which in itself will protect the steel.

It is suggested that after an initial period of one or two months a suitable resistance could be included in the circuit to restrict the current to a value sufficient to maintain protection without allowing a massive deposit of cathode product to accumulate on the steel surface. In this way, anode life would be prolonged, but more important, in this case, the necessary heat transfer characteristics of the transformer shell would not be adversely affected.

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Topic of the Month

Protecting Water Works Steel Structures Cathodically

By FRANK P. MACDONALD*

OF PARTICULAR interest to the water works industry is the application of cathodic protection to plant equipment to reduce maintenance costs and extend the life of expensive structures used in water treatment plants using the same principles and techniques that have proved so useful in protecting elevated tanks.

Structures on which cathodic protection has become an integral part include the sludge blanket type clarifier and softening tanks, the steel shafts and supporting arms for the paddles in the slow mixing flocculator basins and the rake arm structures of clarifiers and settling basins.

At Cincinnati, Ohio, four Dorr clarifiers and two Dorr flocculator basins were erected in 1939 at a cost of \$250,000. The submerged steel in these structures was painted with two coats of red lead when placed in service. During 1947 and 1948 a study was made of various coatings to determine the most suitable for protection of the rake arms of the clarifiers. Various types of paints were applied in test panels directly on the structure, but none of the coatings afforded complete protection because all developed faults during the test. The most satisfactory coating appeared to be a coal tar enamel applied hot to steel cleaned by sand-blasting.

In 1948 the area of the metal to be coated was calculated and the cost of sand-blasting and applying hot coal tar enamel was estimated at \$45,000. Cleaning the metal surfaces and coating would have necessitated taking equipment out of service for an extended period.

In view of the cost of coating the four clarifiers and two flocculators, the use of cathodic protection was investigated.

Similar installations were inspected at the Louisville, Kentucky water plant with the result that the City of Cincinnati contracted for installation of ca-

thodic protection for four clarifier basins and two flocculator basins at approximately half of the estimated cost of sand-blasting and coating. No further surface preparation was necessary prior to application of cathodic protection and it was necessary only to take each basin out of service for a very short period to install the cathodic protection system. The systems are now in their third year of operation. At the end of the first year the basins were drained and inspection indicated that corrosion had been stopped on all submerged steel.

A separate rectifier was furnished for each clarifier and for each flocculator basin. Included in the cathodic protection system are the steel gates at the flume on the west side of the clarifier basins. The following interesting data were obtained during a study of results on one of the clarifiers on April 3, 1951: The rectifier was operating at 4 volts, 12 amperes with water temperature at 44° F. Structure-to-water potentials were obtained at various points on the structure as follows:

	Millivolts
Calomel potential at center drum section	-770 to -1020
Calomel potential above scraper	-820
Calomel potential at gates	-840 to -870

Due to the remote location of the expansion plates in each basin, these plates which are approximately 1 foot wide and 20 feet long were not protected. Potential of this freely corroding unprotected steel was -410 millivolts.

The cost to the city so far has been limited to the cost of the installation and the current for the rectifiers, as the design included a minimum life of three years for the electrodes which are 17ST4 aluminum bar stock. In addition to the initial saving through the installation of cathodic protection, important annual savings in maintenance costs are being realized.

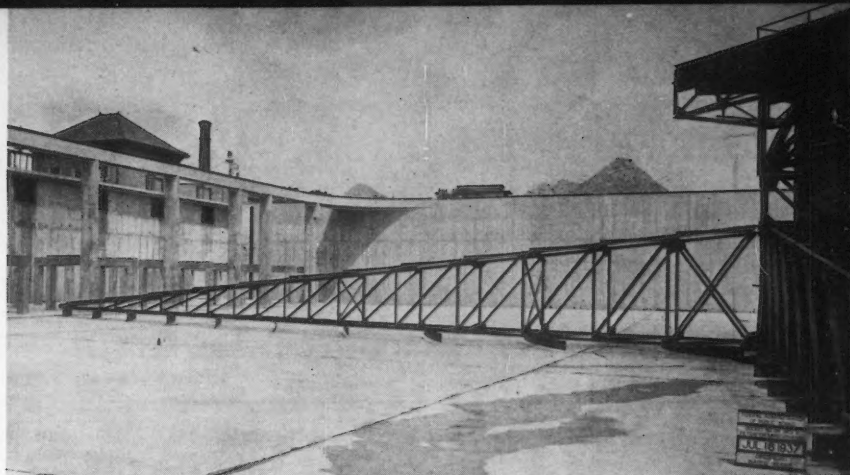


Figure 1—One of four clarifiers at Cincinnati Water Works when new.

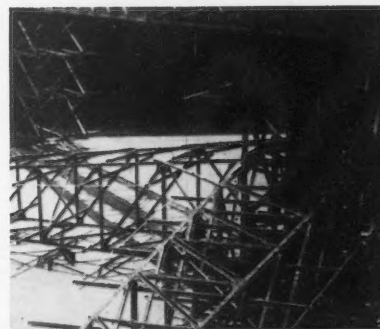


Figure 2—Applied protection on clarifier at Cincinnati Water Works.

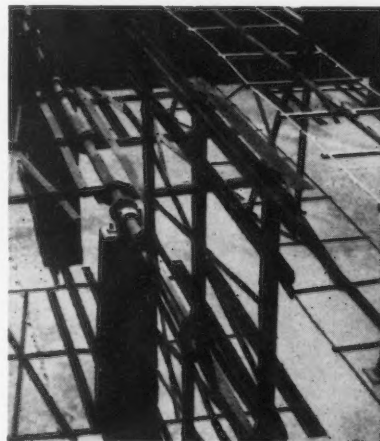


Figure 3—Applied protection on flocculator at Cincinnati Water Works.

Similar results from the standpoint of both corrosion control and savings in maintenance and replacement costs have been experienced by similar installations for clarifiers at other cities including the water plants at Miami, Florida, and Louisville, Kentucky, and in the sludge blanket type of equipment at Springfield and Decatur, Illinois, Benton Harbor, Michigan, Tampa and Clearwater, Florida, etc. Installations are now being made in two Infilco Accelerators at Marion, Indiana, and in a Sapulding Precipitator at South Milwaukee, Wis.

* Electro Rust-Proofing Corp., 1 Main St., Belleville 9, N. J.



Charter Is Asked for Central Wisconsin Section

New Primer Beneficial For Steel Is Described

A new wash primer for steel exposed to a marine environment has effected a remarkable improvement in the corrosion resistance of the so-called topside coating of naval vessels, Baltimore Section was told May 1 by A. L. Alexander of the Naval Research Laboratory. Dr. Alexander spoke at a dinner meeting at Park Plaza Hotel, Baltimore before 31 members and guests on "Role of Organic Coatings in Metal Protection."

The discussion was opened with a review of commonly used inhibitive pigments. A type of protective coating was described as combining active pigment with an extender in a resinous material modified with a plasticizer and perhaps also a toughener.

In the field of coatings specific for marine exposure Dr. Alexander said it was important to evaluate them for corrosion resistance and fouling resistance simultaneously. The new wash primer was discussed at length, and points illustrated with slides. The material, a zinc tetroxychromate-polyvinyl butyral-phosphoric acid coating, was said to be as much a metal treatment as an organic coating.

Also described was the extensive experimental work preceding acceptance of copper flake or powder in place of cuprous oxide for anti-fouling purposes. Because it was known copper acting cathodically in contact with steel would not resist fouling, film conductivity tests were made establishing an upper limit of copper flake content in the coating below which galvanic currents would not be generated.

Philadelphia Has Session On Two Coating Methods

Two coating methods were discussed at the May 16 meeting of Philadelphia Section at the Poor Richard Club, 1319 Locust St., Philadelphia. Dinner began at 6:30 p.m., followed by a business meeting and the two technical papers.

Scheduled speakers and topics were: "Corrosion Prevention of Iron and Steel by the Use of the Metallizing Process," by Vern Smith, technical service manager, Metallizing Engineering Co. and "The Development and Application of Vinyl Resins," by George E. Field, technical service manager, plastic materials, B. F. Goodrich Chemical Company.

HALF-YEAR MEMBERSHIPS

NACE by-laws provide that those applying for Active (individual) Membership in the association subsequent to June 30 shall pay dues of \$5 for the remainder of the calendar year.

- The half-year membership includes issues of CORROSION magazine, July-December inclusive.

NACE CALENDAR

June

- 7 Pittsburgh Section.
- 11 Permian Basin Section.
- 20 Los Angeles Section. Rodger Young Auditorium, Los Angeles.
- 27 Corpus Christi Section.

July

- 9 Permian Basin Section.
- 25 Corpus Christi Section.

Films On Painting Are Viewed at New York

Ninety-one members and guests of Metropolitan New York Section saw two technicolor sound motion pictures on painting techniques at the section's April 18 meeting. During the cocktail hour preceding the meeting the film of the television show held just before the NACE 1951 conference in New York was shown. The meeting was held at Building Trades Employers' Association, 2 Park Ave.

Frank Van Etten of the Bureau of Ships, Navy Department presented the films, Exterior Top-Side Painting. I—Surface Preparation. II—Application. Various mechanical paint removal tools were shown in operation. It was evident cleaning to bare metal is necessary to assure proper bonding. The second film depicted application techniques. A lengthy discussion followed showing of the films.

Two films on painting erroneously reported in the April issue of CORROSION as having been seen by Metropolitan New York Section on March 2 were viewed instead, on April 18 by the section.

A new section of the National Association of Corrosion Engineers to function on a state-wide basis to serve the extensive paper and power industries of Central Wisconsin was organized May 7 at a Milwaukee meeting. The gathering, held at Engineers' Society of Milwaukee Building, was attended by 40, of whom 12 were NACE members. Several applications for membership were received at the meeting. This is the twenty-third local NACE section.

Harold F. Haase of Engineering College, Marquette University, Milwaukee, has been named temporary secretary of a committee to complete preliminary organization plans. A petition for recognition as an NACE Section has been forwarded to Frank L. Whitney, North Central Region director.

Orin E. Andrews, Manager of Research for A. O. Smith Corp., spoke to the gathering on "Fundamentals of Corrosion."

Industrial Applications Of Aluminum Discussed At St. Louis Meeting

Members of St. Louis Section NACE held a joint meeting with the St. Louis Chapter of the American Institute of Chemical Engineers and the St. Louis Engineers Club April 19 at the Engineers Club. The meeting was preceded by dinner at Forest Park Hotel.

Kent R. Van Horn, associate director of research for Aluminum Company of America spoke on "Industrial Applications of Aluminum." His talk consisted of a brief summary of the characteristics, properties and applications of various commercial cast and wrought aluminum alloys. The functions of alloying elements and their effects were described. The talk was illustrated with slides showing characteristics, end uses, results of heat treating, quenching and cold working of the alloys.

Dr. Van Horn, a Case School of Applied Science graduate in 1926 received a doctor's degree in metallurgy from Yale, was research metallurgist at Alcoa from 1929 to September, 1944 and recently was named a member of the Metallurgical Advisory Board for the Department of Defense.



KENT R. VAN HORN

Pittsburgh Program To Be Based on Poll Of Members' Interests

North East Region Board of Trustees met at Webster Hall, Pittsburgh, Pa., May 3. The 8-subject program series for monthly meeting of Pittsburgh Section derived from a mail poll of members was discussed. Tabulation of results will be furnished the region secretary for dissemination to other sections. The trustees also discussed revised procedure adopted by the association's board of directors for reimbursement of local sections.

H. F. McConomy, chairman of Philadelphia Section, distributed a preliminary draft of instructions for the guidance of section officers in discharging their duties. When revised they will be published by North East Region and made available to other groups through Central Office.

A revised calendar of meetings in the region was issued by T. P. May, region vice-chairman, as follows:

SECTION	May	June	Sept.	Oct.	Nov.	Dec.
Philadelphia...	16	..	..	12	..	14
Met. New York	26	..	7	12
Baltimore.....	2	..	4
Pittsburgh.....	..	7	..	..	..	..
W. New York..	18	..	..	19
Joint Reg.-Sec.	10	..	..
Trust.....	18	..	..	4

Present besides those mentioned were L. B. Donovan, H. L. Hamilton, E. R. English, W. F. Fair, Jr., G. L. Cox, and V. V. Kendall, trustees. Also present were R. H. Lynch, formerly regional director and J. M. Bialoski, vice-chairman Pittsburgh Section.

New Officers Named By Shreveport Section

New officers of Shreveport Section were elected as follows May 10 at a meeting at Caddo Hotel:

T. L. Holcombe, Holcombe & Stearns, Inc., chairman; M. J. Olive, Arkansas Natural Companies, vice-chairman; J. M. Smith, Interstate Oil Pipe Line Company, treasurer; W. F. Levert, United Gas Pipe Line Company, secretary.

The annual barbecue of the section was scheduled for June 15 at a nearby lake.

W. A. Broome of Arkansas Louisiana Gas Co., who gave the report about the corrosion school, said main topics would be fundamentals, coating application, how, when and whys of cathodic protection, instruments and their uses and internal corrosion.

A panel discussion led by Mr. Broome was held and because limited time prevented discussing many questions it was decided to resume the program at a later meeting.

The section will not meet during July and August.

Committeemen Named For Regional Meeting

B. P. Ledbetter, of the City of Corpus Christi's gas department has been named chairman of the General Committee for the South Central Region's October 18-20 meeting at Corpus Christi. Other members of the committee are Messrs. Fleming and Thomas F. P. Kelly of James E. Mavor Co., Houston, and George A. Mills, Central Power and Light Co., Corpus Christi.

Chairmen are to be named soon for the following committees: Local arrangements, entertainment, transportation and field trips.

Corpus Christi Section Elects New Officers

New officers were installed by Corpus Christi Section at a dinner meeting March 28 attended by 18 members and two guests. New officers are: Thomas S. Moffatt, Jr., Southern Alkali Corp., chairman; John W. Nee, Briner Paint Manufacturing Co., vice-chairman; and Charles F. Ward, Magnolia Petroleum Co., secretary-treasurer, all of Corpus Christi.

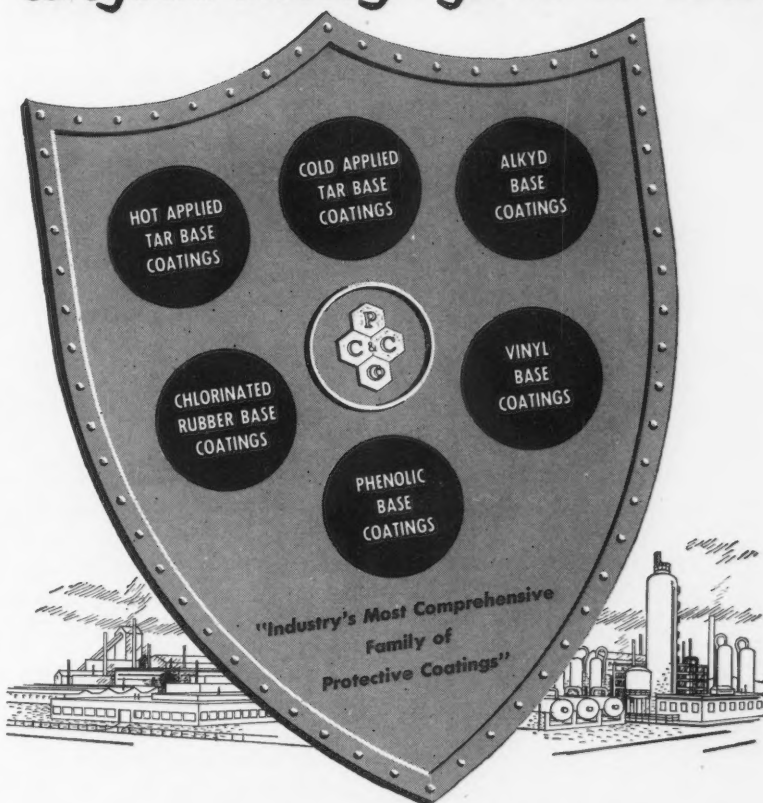
H. W. Butterbaugh of American Brass Company addressed the group on copper and copper alloys.

Next scheduled meeting of the section is June 27.

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LaQue Discusses Effect Of Alloying Elements

A slide-illustrated talk on "Effect of Alloying Elements on the Corrodibility of Iron," was given by F. L. LaQue, head of the Corrosion Engineering Section, The International Nickel Co., Inc., New York City, to 94 members and guests of Houston Section May 8 at Guy Francis' Restaurant, Houston. Effects of chrome, nickel, niobium (columbium) and molybdenum on corrosion rates in several environments were discussed and illustrated. The role of other factors in evaluating performance of steel also were discussed. For example, location of the test site, whether industrial, seashore or rural influences the

corrosion rate of ferrous alloys. Mr. LaQue also told of the possible value of the color and physical appearance of rust in testing steels' corrosion resistance. A dark, finely grained scale usually is more adherent and protective.

Additional factors include angle of exposure of the specimen and rain wetting and drying cycle. These variables, Mr. LaQue emphasized, make necessary the keeping of complete records of exposure conditions.

Eddie Dyer, formerly manager of the St. Louis Cardinals and now a Houston oil and insurance man told several baseball stories before the technical presentation.

Plans are under way for a social meeting for members and their wives during June.

Members Surveyed by Western Region on Meeting in Fall

Western Region is surveying the interest of members of NACE on the West Coast in two alternative schedules for a regional meeting to consist of technical sessions, field trips and social events. Evidence of interest in the proposal and in seven technical areas as well as in kinds of field trips desired is requested in a questionnaire mailed to members over the signature of L. L. Whitneck, Western Region Chairman.

The two alternates proposed are: A one-day meeting on Friday consisting of three items in the morning, or six symposia in two separate non-conflicting items may be arranged to be held simultaneously, and a choice of one of three field trips. The day would close with a banquet featuring light entertainment.

The second alternate would be a day and a half meeting, on Friday and Saturday morning consisting of three items Friday morning and three Friday afternoon, a banquet Friday night with a light program and a choice of one of three field trips Saturday morning.

A number of technical areas also are listed in the questionnaire, with places for members to indicate to what extent they can contribute to the event and attend field trips.

W. E. Kirkendall, secretary-treasurer, Los Angeles is compiling the data.

H. O. Teeple Addresses Salt Lake Section

H. O. Teeple of International Nickel Co., Inc., New York City, spoke to 14 members and 11 guests of Salt Lake Section May 9 at Mountain Fuel Supply Co. auditorium, Salt Lake City, Utah. His topic "Corrosion Processes and Factors" covered mechanisms of corrosion under conditions of concentration, temperature, velocity, conditions of active and passive metals in relation to concentrations of solutions.

STANLEY GILL

Stanley Gill, of Houston, died May 7 at a Huntsville hospital. Mr. Gill was interested in pipeline corrosion mitigation during the interval 1924-30 when he was with Gulf Production Company. A chemical engineer, he was a graduate of Columbia University.

Piper to Talk

Dr. John Piper of Detroit Edison Company was scheduled speaker at a May 10 meeting of Detroit Section at the Rackham Bldg.

Reports of meetings of subdivisions of NACE should be sent to Central Office in sufficient time to meet the publication deadline of the tenth of the month preceding date of issue.



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For a period of 12 years the Nelson Electric Manufacturing Company has been furnishing Phenolic Insulating Materials for pipe nipples and the insulation of pipeline flanges. We introduced the use of thin-wall tubing sleeves for insulating the studs in standard flanges, without requiring re-drilling of the flange and providing smaller studs. We now offer flange insulation, packaged for immediate shipment on the more common sizes.

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RUST-OLEUM can be applied even over rusted surfaces—no sandblasting or chemical cleaning is usually required. It is particularly effective for use in difficult-to-get-at places—where it is impossible or excessively costly to sandblast or chemically clean the metal. It is not necessary to remove all the rust. Just use sharp scraper and

wire brush to remove rust scale and loose rust.

For more than 25 years RUST-OLEUM'S capacity to stop rust has been demonstrated convincingly in many types of industrial applications by nationally-known manufacturers and leading railroads.

RUST-OLEUM can be obtained promptly from Industrial Distributors' stocks in principal cities of the United States and Canada. See our complete catalog in *Sweet's*, which also lists your nearest source of supply. Or, write on your company's letterhead for full information.



Available in many
COLORS
aluminum and white

Beautifies as
it Protects

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RUST-OLEUM CORPORATION
2436 Oakton Street, Evanston, Illinois

Wrapped Pipe Coatings Discussed at Meeting Of San Francisco Group

D. R. Loper of the Engineering Department of Standard Oil Company of California addressed the April 25 meeting of San Francisco Bay Area Section NACE on "Coatings for Buried Pipe Lines". Forty members and guests enjoyed dinner at El Jardin Restaurant, San Francisco.

The speaker discussed conventional wrapped coatings, including the following salient points: 1) it is almost always economical to apply some form of coating, even when cathodic protection is employed; 2) the type of coating used depends on ease of replacing pipe, soil conditions, size of job and engineering considerations, such as payouts; 3) use of the more expensive but durable coatings, such as 5 or 7-wrap coatings or Somastic, effect considerable savings over the less expensive coatings under severe conditions or where pipe maintenance is difficult, such as at river or highway crossings and where pipe failures may cause ill-will, such as in urban areas.

A lively discussion followed the meetings.

A joint business meeting was held April 27 with members of ASTM when plans were made for the October or November meeting at which the two organizations will be host to F. L. LaQue of International Nickel Co., New York. Mr. LaQue will deliver the Marburg lecture, with special emphasis on points of interest to West Coast Engineers.

Advance notices of meetings of organizations other than NACE engaged in corrosion work will be published on request in the "Meetings" column.

1952 Short Course at Washington University, St. Louis, Is Scheduled

Preliminary planning of a short course on corrosion during 1952 at Washington University, St. Louis, Mo., has been completed. Dates on which the course will be given are September 8-12, 1952. Arrangements were made at a conference May 4 among W. H. Reals, dean, University College; L. E. Stout, dean, School of Engineering; D. A. Fischer, assistant dean, School of Engineering, all of Washington University and F. L. Whitney, Jr., NACE North Central Region Director.

Dr. Reals will be in charge of activities for the university with Messrs. Stout and Fischer as committee members and co-ordinators. Mr. Whitney, acting for NACE, will prepare the technical program, secure lecturers and act in liaison between the university and the association. The final program will be approved by the university committee and by the NACE Committee on Education.

The university probably will make arrangements regarding financing, housing, registration and other matters. The registration fee will go entirely to the university or an arrangement may be perfected allowing a portion of it to accrue to the association as dues, in a manner similar to arrangements used at previous short courses with which the association has been affiliated.

The association also will assist by providing publicity and in other ways.

An opportunity will be sought to provide some social activity during the course, possibly related to the university's centennial observance, to be underway in 1952.

TP-16 Subcommittees' New Chairmen Named

New chairmen for TP-16 subcommittees have been given as follows by Irwin C. Dietze, chairman:

TP-16A Stray Railway Current Electrolysis. M. D. Fletcher, chairman, Illinois Bell Telephone Co., Chicago; J. Svetlik, co-chairman, Northern Indiana Public Service Co., Hammond, Ind.

TP-16B Corrosion of Lead and Other Metallic Sheaths. B. B. Reinitz, chairman, The Okonite-Callender Cable Co., Paterson, N. J.; T. J. Maitland, co-chairman, American Telephone & Telegraph Co., New York.

TP-16C Cathodic Protection of Cable Sheaths. W. J. Schreiner, chairman, Cincinnati Gas & Electric Co.; R. M. LaWall, co-chairman, American Telephone & Telegraph Co., Cleveland.

TP-16D Tests and Surveys. L. J. Gorman, chairman, Robin Beach Engineers Associated, Brooklyn; A. K. Joecke, co-chairman, Consolidated Edison Co. of New York.

Five New Members Are Appointed to TP-7

Five new members have been added by Technical Practices Committee 7—Materials for Use in High Temperatures. They are F. L. Whitney, Jr., Monsanto Chemical Co., St. Louis, Mo.; J. P. Casey, Jr., Crane Co., Chicago, Ill.; W. Z. Friend, International Nickel Co., Inc., New York City; E. N. Skinner, International Nickel Co., Inc., New York City and K. E. Luger, K. E. Luger Company, Houston, Texas.

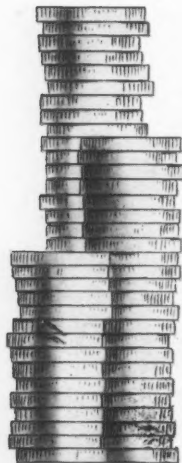
The committee is compiling a report including literature references on the subject of high temperature corrosion. Many topics assigned to members have been completed and when some additional references have been examined a report will be prepared for submission to NACE for publication. M. A. Scheil, A. O. Smith Corp., committee chairman and J. J. Heger, United States Steel Company, committee secretary are directing completion of the committee's first report.

Arrangements Are Made On Sulfide Inquiry

The International Nickel Company's \$5000 grant for research into sulfide corrosion cracking has been turned over to Yale University for use under the supervision of W. D. Robertson, professor at Hammond Metallurgical Laboratory, Yale University, New Haven, Conn. The research is to be conducted under a plan developed by NACE Technical Practices Committee 1—Corrosion of Oil and Gas Well Equipment and agreed to by International Nickel. The funds are to be allocated annually as follows: \$2000 to finance a graduate student, \$1000 for supervision by Prof. Robertson and the balance for costs associated with the project.

TP-1 will review papers prepared reporting results of the research.

PROFITS ARE SAVED NOT MADE



Whether it be a gas or water distribution system, a transmission pipe line, tank bottom, off-shore drilling platform, condenser or water tank, or ship hull, corrosion losses can be stopped—can be converted to profits.

Electro Rust-Proofing services are designed to help you make these savings. First, ERP offers a complete engineering service on either a contract or per diem basis to suit your individual needs. All survey and design work is conducted by qualified cathodic protection engineers fully equipped with the necessary precision measuring instruments and other testing apparatus. Second, ERP's Contract Department is available to furnish, install and maintain all cathodic protection equipment and materials which may be required.

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E-16

CATHODIC PROTECTION FOR ALL BURIED AND SUBMERGED STRUCTURES

1952 Galveston Conference Officials Named



WALTER F. ROGERS
General Chairman



ROBERT L. BULLOCK
Technical Program Chairman



JACK W. HARRIS
Exhibition Chairman



CHARLES G. GRIBBLE, JR.
Local Arrangements Chairman

The following officials have been named for the 1952 Conference and Exhibition of the National Association of Corrosion Engineers to be held in March, 1952 at Galveston, Texas:

Walter F. Rogers, Gulf Oil Corp., Houston, general chairman;

Robert L. Bullock, Interstate Oil Pipe Line Co., Tulsa, Okla., technical program chairman.

Jack W. Harris, Cameron Iron Works, Houston, exhibition chairman.

Charles G. Gribble, Jr., Metal Goods Corp., Houston, local arrangements chairman.

The eighth annual conference will be held in the Southwest for the first time since the 1944 meeting at Houston. Headquarters of the Galveston conference will be the Galvez Hotel.

Deadlines Are Given On Discussions for New York Papers

Written discussions to papers presented at the March, 1951 NACE meeting in New York, requests for which were mailed early in April, should be returned to Central Office before July 1, according to a schedule approved by Dr. Ivy Parker, editor of *Corrosion*. After that date, written discussions on hand will be sent to authors of papers for reply.

Authors of technical papers presented at New York may expect to receive copies of discussions on or about July 15, and they will be asked to return the discussions, together with their own comments to Dr. Parker, about August 1.

It is considered desirable to print remarks and discussions about papers with the papers to which they refer whenever that is feasible. When the paper's publication precedes the discussions, the next best alternative is to publish discussions together, thereby minimizing reference work. Under this schedule it is unlikely that many discussions will be published before the October issue.

A large number of written discussions have been received at Central Office, but many more have not been returned. Dr. Parker requests those who can to send in their discussions quickly and minimize the detail work of following them up.

Despite these deadlines, discussions received at any time are given full consideration.

West Berlin Technical Magazine Is Received

Werkstoffe und Korrosion, a technical magazine published in West Berlin is now being exchanged with *Corrosion*, following approval of the arrangement by members of the association's publication committee.

Nodule Method Measures Electrodeposits' Adherence

A simple, inexpensive method of determining the adhesion of commercial electrodeposited coatings has been developed at the National Bureau of Standards by Abner Brenner and Virginia Morgan. The method involves plating a cobalt mushroom-shaped nodule to the surface of the plated material and then measuring with a spring balance the force necessary to strip the plated coating from the basis metal, or as is the case in some tightly-adhering coatings, the electrodeposited coating and parts of the basis metal adhering.

The method involves coating the piece to be tested with a stop-off material,

affixing plastic washers (the inside holes of which are tapered) to the fluid stop-off, drilling away stop-off material inside the washers and plating a nodule onto the exposed plated surface. The areas so plated measure about 1/16-inch in diameter. Visual check of the size of the exposed plating is made with a transparent gauge ruled with concentric circles of varying diameters.

Adhesion test limits are to the tensile strength of the cobalt nodule, about 75,000 lb. sq. in. So far no method has been developed to test adherence of bright nickel coatings because the cobalt nodule does not adhere tenaciously enough to the nickel. A skilled operator can prepare and test about 10 specimens a day, and electroplating the nodule usually is accomplished overnight. (This based on NBS Technical Report 1541.)

Schedule Is Given For Nominating Committee Activities

Schedule for nomination and election of officers and directors of the National Association of Corrosion Engineers has been released by A. B. Campbell, NACE Executive Secretary as follows:

(Dates are those on which the activity noted is to be completed.)

March 1, 1951—Formation of nomination committee. (Completed.)

August 15—Nomination of candidates and report to the secretary.

September 10—Preparation and mailing of nominating committee report to NACE members.

October 15—30 to 35 days for members to prepare and file nominations by petition.

November 10—Preparation and mailing of letter ballots to members.

December 29—Period allowed members to return letter ballots.

January 10, 1952—Period allowed to count ballots and prepare tellers' report.

March 11, 1952—General business meeting.

Members of the nominating committee are: Mars G. Fontana, E. C. Gosnell, Vance N. Jenkins, E. O. Kartinen, Ivy M. Parker, T. P. May and W. H. Stewart.

Advance notices of meetings of corrosion interest should be sent to CORROSION in sufficient time to permit publication in an issue distributed before the meetings are held.

Hackerman Re-Named Education Committee Chairman for 1951

Dr. Norman Hackerman of the University of Texas, Austin has accepted chairmanship of the NACE Education Committee for the second successive year.

Steps are being taken to change the association's articles of organization to make the Education Committee chairman an ex-officio member of the board of directors in the same status as the chairmen of other permanent committees. Until the change is effected, steps are being taken for informal participation in the board's deliberations by the chairman of the committee.

James T. MacKenzie Is Given Herty Medal

Georgia Section of the American Chemical Society awarded the Herty Medal to Dr. James T. MacKenzie at Georgia Southern College for Women, Milledgeville, Ga. on May 5. This award is given annually to an outstanding chemist in the Southeastern states. Dr. MacKenzie was first of the 19 recipients of the award whose whole career has been devoted to industrial work.

He gave a historical account of the development of the cast iron pipe industry during 1915-51.

Dr. MacKenzie was a member of the NACE Board of Directors representing the South East Region 1950-51.

Exhausted Issues of Corrosion Are Listed

Central Office files have been exhausted of the following issues of Corrosion and it no longer is possible to sell individual copies:

1947—January, March, July, September and November.

1948—May, June, July, August.

1949—January, February, July, October.

1950—January, February, April, May, July.

1951—January.

Persons who wish to secure copies of material published in these issues are advised to order photostatic or microfilm copies from established libraries offering this service. Central Office, NACE, 919 Milam Bldg., Houston Texas, will supply photostat copies of material only from those issues which are exhausted. The charge will be based on the cost to the association of providing the copies.

Ulick R. Evans Speaks

Ulick R. Evans, Reader in the Science of Metallic Corrosion at Cambridge University addressed the inaugural meeting of the Corrosion Group of the Society of Chemistry and Industry at the Royal Institution, Albemarle Street, London W. 1 on May 17. His topic was "The Corrosion Situation: Past, Present and Future."

W. H. J. Vernon has been nominated chairman and S. G. Clarke honorary secretary.

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holds larger quantities of enamel on pipe . . . is not subject to deterioration thereby providing longer life for protective coating.

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Now—you simply "pull the zipper" on corrosion problems



Dresser ZIPCOAT for welded joints zips over weld area, fits closely to the pipe. 30" lengths.

NEW DRESSER ZIPCOATS* GIVE SURE PROTECTION, SUPERLATIVE DIELECTRIC STRENGTH

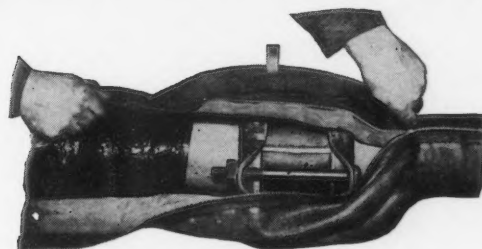
"As easy as zipping up a jacket" is what workmen say about Dresser's new ZIPCOATS. They install ZIPCOATS in 1/10 of the time it takes to coat a joint. You get protection that equals or exceeds that offered by the mill or yard-wrapped pipe.

And look at the hazards you avoid: there's no flame; no heating, hauling or messy application of hot stuff; no danger from fumes or burns.

Can be installed in any weather.

Write today for descriptive material and price list.

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Dresser ZIPCOAT for couplings is easy to install over joint and pipe ends—all in one quick operation. Has bleeder valve to vent air during backfilling.

Dresser ZIPCOAT for insulating joints is made like the ZIPCOAT for welds, but in ten-foot lengths. Installing one on each side of an insulating joint that's protected with a ZIPCOAT for couplings gives ultimate protection. Eliminates costly boxing and filling with dope. Immediate trench backfill saves time.



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Dresser Style 39 Insulating Couplings with new plastic gaskets insulate effectively and are the simplest insulating type joint to install. Sizes $\frac{3}{4}$ " to 30" and up.



New Dresser Bonding Method saves up to 50% of cost; materials preformed

Fast bonding, giving low resistance with preformed Dresser Bond and 5-second chemical welding method. Needs no special skill, no bulky equipment. Makes homogeneous weld area, eliminates surface contact variables. Compact kit of 50 preformed bonds includes all materials needed for installing.

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Amines System Corrosion Paper Is Scheduled

Scheduled for presentation May 15 during the American Institute of Chemical Engineers' Kansas City meeting in the Light Hydrocarbons Symposium was the following paper:

No. 20. Corrosion in CO_2 - H_2S -Amine System, by K. L. Hujsak, G. R. Davis and E. C. Carlson, Stanolind Oil and Gas Co., Tulsa, Okla.

Increased use of sour natural gas has multiplied plants using amines for sweetening. In one plant reboiler tube corrosion of the amine regenerator was so severe tube bundle failures occurred in two to three months. Operating conditions of the system were studied on

a pilot scale and it was found the metal attack could be reproduced when the amine contained small residual amounts of hydrogen sulfide and the heat medium oil was 500 degrees. Reduction of oil temperature to 350 degrees F practically eliminated pilot unit corrosion.

Thermodynamics Group To Meet in Switzerland

The third meeting of the International Committee of Electrochemical Thermodynamics and Kinetics will be held August 6 at University of Bern, Switzerland. Pierre Van Rysselberghe, president of the committee, advised from Milan, Italy that further information

may be obtained from him at the University of Oregon or from Dr. M. Pourbaix, secretary of the committee, University of Brussels, Brussels, Belgium.

Topics to be discussed include electrochemical behavior of metals and non-metals, potential-pH diagrams, corrosion, electrical double layers, definitions and nomenclature of electrochemistry. Complete texts of papers to be presented are to be in the hands of the secretary by July 1. Correspondence should be sent by air mail.

Electrochemical Society To Give Medal for Work in Corrosion

Original and outstanding contributions to the knowledge of corrosion and its control are qualifications for the recipient of the biennial Palladium Medal, established by the Electrochemical Society at its Washington, D.C. meeting April 12. The medallist will be selected by a committee composed of scientists prominent in the fields of corrosion and electrochemistry.

The medallist will be invited to address the national fall meeting of the society at which the medal will be presented. First presentation will be made in 1951. In addition to the medal the recipient will receive traveling expenses and an honorarium.

Royalties from the sale of the Corrosion Handbook, sponsored by the society have in part made possible the award. The medal will be struck in the rare and precious metal palladium and will have interesting features of design.

Saving Spent Plating Water Recommended

An argument for saving by purification of spoiled plating solutions, rather than attempting to dump the solutions into a stream is advanced by the Ohio River Valley Water Sanitation Commission.

Citing an example of a 100-gallon cyanide solution containing only five ounces of cyanide per gallon, the commission points out that in a state where the permissible concentration of cyanide in waste water discharge is 0.10 ppm it would take 37,500,000 gallons of diluent water to bring the concentration to the legal maximum. This is enough water to cover a football field 105 feet deep.



WITHOUT REMOVING THIS PIPE FROM THE GROUND, holes resulting from exterior or interior corrosion have been permanently filled by the thin coating of cement mortar mechanically applied to the interior of the pipe by the Centriline process.

Internal corrosion has been *eliminated*. Centriling also increases

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The ingenious Centriline machine utilizes centrifugal force in applying the cement. Pipes in diameters of 4" to 144" can be lined by Centriline at a *fraction* of the cost of installing new pipes. Make pipes better than new through cement lining.



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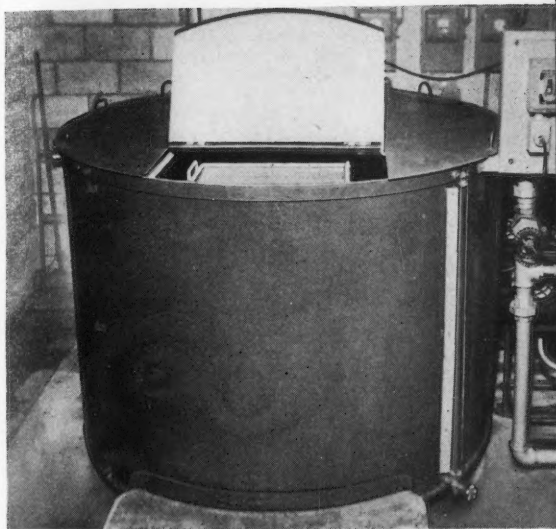
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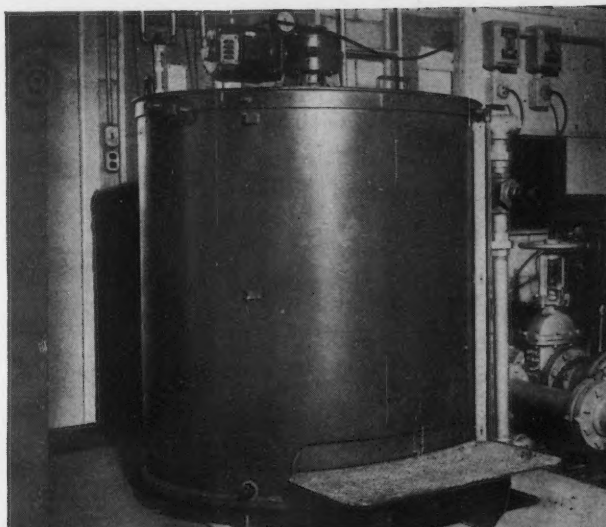
MEMBERSHIP CARDS AVAILABLE

Association members in good standing will be issued on request a membership card in the National Association of Corrosion Engineers. Address requests to A. B. Campbell, Executive Secretary, 919 Milam Building, Houston 2, Texas.

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More and more oil men, chemical manufacturers, processors, are finding that coatings based on VINYLITE Brand Resins cut the long-time cost of metal protection down to rock bottom!

Fundamental reason for this is the basic inertness of these resins...their powerful resistance to attack by oils, greases, water, salts, alkalis, most strong acids, and most other chemicals.

Add to this the fact that, when properly formulated, they are easy to apply by conventional methods, they air-dry rapidly, and they stay intact

for long periods, maintaining their integrity and bond. Inherently tough, they are also resilient and able to withstand impact, shock and abrasion. They protect containers from contents and spillage. They protect contents from injury by containers.

You will find coating systems based on VINYLITE Brand Resins priced comparably with other quality finishes. But you'll find renewed savings year after year in the greatly reduced maintenance and refinishing costs that these long-lasting, chemical-resistant coatings make possible.

For more information and a list of representative suppliers, write Dept. KI-69.

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BOOK REVIEWS

REPORT, PRESIDENT'S WATER RESOURCES POLICY COMMISSION. Several volumes, pamphlets, and parts of volumes giving the recommendations of the Policy Commission appointed in January 1950. Other information itemized herein. All documents may be purchased from Superintendent of Documents, Washington 25, D. C.

A Water Policy for the American People. Vol. 1. A coordinated national program for the development of water resources, together with specific recommendations on policy. \$3.25.

Ten Rivers in America's Future. Vol. 2. A study of 10 river basins in different parts of the country, a discussion of the problems of each and a mass of hitherto unpublished material. Each basin study has been published separately. Separate sections are sold at prices varying from 50 cents to \$1 a copy. The whole volume is \$6.00.

Water Resources Law. Vol. 3. A summary of federal law. \$2.25.

Summary of Recommendations, 15 cents.

A ROMANCE IN RESEARCH. The Life of Charles F. Burgess. By Alexander McQueen, with technical appendix by Oliver W. Storey. 6 x 9 1/4, 429 Pages. The Instruments Publish-

ing Company, 921 Ridge Ave., Pittsburgh 12, Pa. \$6.00.

Charles F. Burgess, whose favorite field of research was electrochemistry, received many high scientific honors and awards during his career. Born in Oshkosh, Wisconsin, February 27, 1872 he attended and afterward became a professor at Wisconsin University. He was one of those attending a meeting of the American Electrochemical Society in April, 1902, which later became The Electrochemical Society. He was elected president of the society in 1907 after publication of results of his research into the production of pure electrolytic iron and its uses.

He was instrumental in the establishment at Wisconsin in 1899 of a four-year course in Applied Electrochemistry. He later was put in charge of the department of chemical engineering and was a full professor at the school from 1905 to 1909.

In 1910 he established and incorporated the Burgess Laboratories, resigning from the university in 1913 to devote his full time to industrial research.

The Burgess Battery Company was incorporated in 1917, in time to help train top engineers and chemists in the characteristics of new types of cells useful in World War I.

As a consultant for the French Battery and Carbon Company, in 1908 he was permitted to buy stock in the company at 10 cents a share as compensation for his services. The company had been losing money steadily until he became associated with it, and within six months it was breaking even. This company afterwards became the Ray-O-Vac Company.

During the last years of his life Burgess devoted his energies to the development of handicrafts.

Burgess did considerable experimental work on zinc, nickel, copper and lead electrodeposition, electrolytic removal of asphaltum, lacquer and enamel coatings. He also investigated Sherardizing, discovering iron could be Sherardized.

He devoted much of his time at the University of Wisconsin to the problem of corrosion. He was interested in development of electroplated zinc, and in fundamental studies dealing with the corrosion of iron. He was among the first to suggest that the superior corrosion resistance of old iron resulted from accidental copper and other impurities it contained.

Burgess' other work included electrochemical processes, electric furnaces, electrochemical and electrical devices.

THE ROYAL DUTCH PETROLEUM COMPANY. 1890-1950. 6 1/2 x 9 7/16, 205 pages. Cloth. Privately printed at The Hague. Limited distribution.

A beautifully designed, printed and illustrated book issued by the Royal Dutch Petroleum Company on the occasion of its Diamond Jubilee. The book relates the history of the company from its inception, describes past and current exploration, production, processing, chemical industry, transport, scientific research, marketing and personnel.

REFERENCE BOOK ON INSTRUMENTS. A Reference Book on Corrosion Instruments for Electrolysis, Corrosion and Cathodic Protection Testing. Compiled by Subcommittee on Instrumentation, American Gas

(Continued on Page 14)

WRAP UP THE JOB WITH RUBEROID IMPERIAL ASBESTOS PIPE LINE FELT



Pipe line engineers know that there is no finer pipe protection than the long-fibered strength of Ruberoid Imperial Asbestos Felt. They have found that under most soil conditions Ruberoid pipe line felt, in conjunction with a proper enamel coating, provides the best defense against both physical and corrosion hazards. The dangers of jagged rocks, soil distortion, settlement and electrolysis are minimized with this more lasting protection.

That's why Ruberoid asbestos pipe line felt was chosen as the protective wrapping for the new 26" gas line from Kentucky to Buffalo, N. Y. Built by the Tennessee Gas Transmission Company, this gas line is assured of long-range economy in maintenance by the enduring performance of Ruberoid Imperial Asbestos Pipe Line Felt.

Weather-Proof Package at slight additional cost

The weather hazards of field-wrapping jobs are greatly reduced by this exclusive Ruberoid development—a new package, constructed of water-proofed kraft and special edging seal—available on special order at a slight additional cost.



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The effectiveness of Santolene C has been proved in the laboratory and in the field. These findings have been confirmed by a major oil company

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Santolene C is product-soluble. It burns completely with the fuel, leaving no residues whatever. Diesel and gasoline engine tests have demonstrated that Santolene C has no effect on engine cleanliness, injector fouling or any other factor of engine performance.

For technical information on the use of Santolene C to solve corrosion problems, write, wire or telephone MONSANTO CHEMICAL COMPANY, Organic Chemicals Division, 1700 South Second Street, St. Louis 4, Mo.

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Book Reviews—

(Continued from Page 12)

Association. 8½ x 11 inches, loose leaf. Paper Bound. Text Section 47 pages. Thumb indexed catalog section. Published by American Gas Association, 420 Lexington Ave., New York 17, N. Y., Per Copy, \$1.50.

This reference book, compiled under the direction of M. C. Miller, chairman of the American Gas Association Subcommittee on Instrumentation, was distributed to about 1000 members of the American Gas Association at Memphis in April. Additional copies were prepared for sale at approximately the cost of production and mailing.

The text section includes articles dealing with general characteristics of electrical instruments for corrosion investigations, high voltage inspection of above-ground pipe coatings, location of underground pipe coating faults, and several types of meters and testing equipment. The catalog section contains material supplied by manufacturers of voltmeters, ammeters and shunts, combination test sets, earth resistivity meters, pH meters, pipe locators, holiday detectors, reference electrodes and miscellaneous testing equipment.

The American Gas Association contemplates supplying owners of record of this book with revisions and additions to the text and circulars. Additional text material on other corrosion testing subjects also is contemplated.

SYMPOSIA ON VARNISH AND PAINT CHEMISTRY. Published by New York University College of Engineering. For copies send remittances in advance to V. W. Palen, Bureau of

Public Information, NYU College of Engineering, New York 53, N. Y.
1948 Symposium, per copy.....\$2.00
1949 Symposium, per copy.....4.00
Reprinted papers delivered at subject symposia. Corrosion interest content reported in Corrosion, February 1950, Page 4 News Section.

Awards Committee Members Are Named

The following have been named members of the National Association of Corrosion Engineers to make recommendations of persons to receive the 1952 Speller and Whitney Awards: R. B. Hoxeng, V. V. Kendall, R. B. Mears, H. M. Trueblood, F. W. Verecke, F. L. Whitney, Jr., R. L. Bullock, Oliver Osborn, F. A. Rohrman, L. R. Sheppard, A. H. Gropp, Ivy M. Parker, I. W. Dietze and Vance N. Jenkins, chairman. Another member is scheduled to be named.

FREE Reprints While Supply Lasts

The Influence of Stress on Corrosion, by Julius J. Harwood, Office of Naval Research, Washington, D. C. Reprinted from CORROSION, Vol. 6, No. 8 and 9 (1950). A paper presented at the NACE meeting, St. Louis, Mo., April, 1950.

Address your request to: Norman E. Hamner, Managing Editor, Corrosion, 919 Milam Bldg., Houston 2, Texas.

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Effects of Prior Stress on Fatigue of Aluminum Alloys*

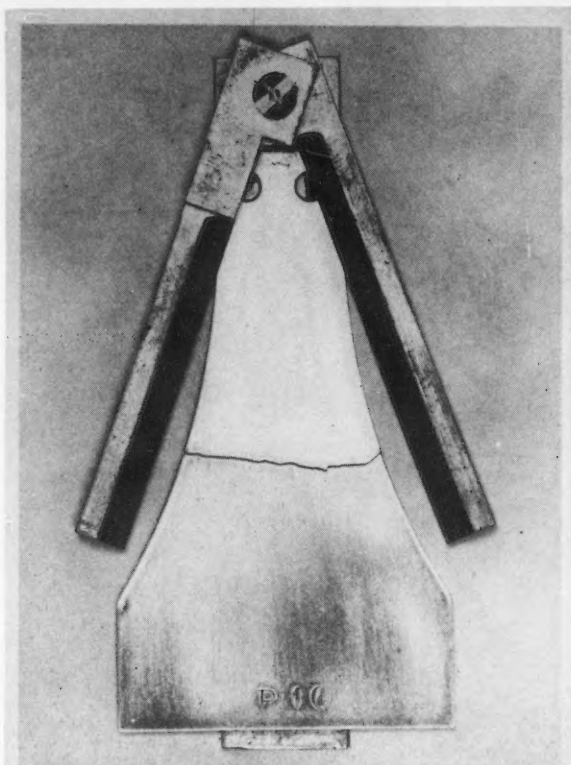


Figure 1. Fatigue-test specimen of aluminum alloy in special measuring jig. Structural members made of aluminum alloys may be given longer active fatigue life if they were prestressed before being placed in operation, according to results of a laboratory investigation at the National Bureau of Standards. Two means of prestressing were employed. In the first, a rather high static load was applied to the specimen before the start of the fatigue test. In the second, the specimen was stressed in the fatigue-testing machine for a predetermined number of cycles at one amplitude, and then carried to failure at a second amplitude. Although conventional repeated-bending fatigue-testing machines were used, the design of the specimen was new (illustrated). Another innovation is a special jig (specimen in jig) which measures the specimen before testing and automatically locates the point at which the stress will be a maximum. The specimen also illustrates the manner in which fracture took place.

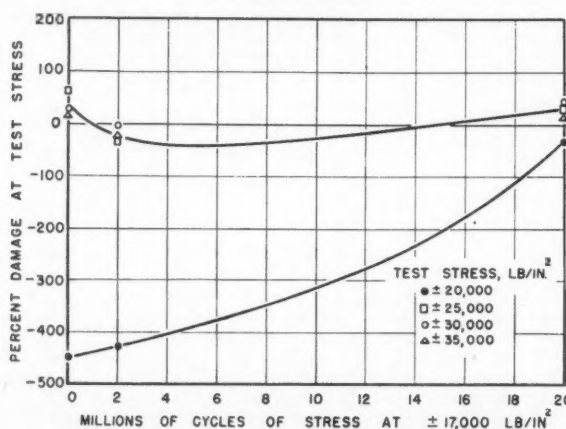


Figure 2. (Graph) Effect of dynamic prestressing at 17,000 pounds per square inch on fatigue strength of 24S-T aluminum alloy sheet. Specimens were stressed at 17,000 pounds per square inch in the fatigue-testing machine for a given number of cycles (plotted along the abscissa) and were then carried to failure at another stress. The relative fatigue life of the prestressed specimens as compared to the original material is plotted as the ordinate. Negative values of the ordinate indicate that the prestressed specimens ran a greater number of cycles before failure than did specimens of the original material. The first points shown represent only 2000 cycles of prestress, but even this produced an improvement of more than 400% in the fatigue life at a slightly higher stress (20,000 pounds per square inch).

THE LIFE of aluminum alloys that are subjected to vibration and other repeated or fluctuating stresses may be materially affected by applying stress to the material before it is placed in operation. Recent investigations at the National Bureau of Standards have shown that this treatment, known as prestressing, in some instances increased the fatigue life manifold. This was especially noticeable at lower stresses when a comparatively small number of cycles of dynamic prestress were applied. On the other hand, there were cases in which little if any improvement resulted and at some stresses the fatigue life was shortened by the prestress. These studies were carried out by J. A. Bennett and J. L. Baker in the Bureau's mechanical metallurgy laboratory to evaluate the effects of both static and dynamic prestress on the fatigue properties of structural aluminum alloys. Similar studies have been previously made on aircraft steel.

A metal will often fracture when a pulsating load is applied for long periods of time, even though the maximum stress is much less than that which the metal can withstand if the load were steady. This phenomenon, known as fatigue, is the primary cause of failure in machine elements and other structural members to which varying loads are applied in service. Because of this, the fatigue properties of structural materials are important in the design of dynamically stressed structures. These properties are usually studied by applying a fluctuating load of constant amplitude to a specimen and counting the number of cycles which are required to fracture the specimen. In tests of aluminum alloys, it is not uncommon to find fractures occurring after as many as 500,000,000 cycles of stress, the number of cycles to fracture decreasing as the stress amplitude is increased.

One of the difficulties encountered in applying results of laboratory tests to practical construction arises from the fact that, in many structures, the stresses vary in a random manner. An airplane wing, for example, must support not only the weight of the plane, which is a steady load, but also a fluctuating load due to vertical gusts. To approximate this situation, the cumulative effect of fatigue stressing at two or more different amplitudes was evaluated, using aluminum alloy sheet specimens.

Two Means Employed

Two means of prestressing were employed. In the first, a rather high static load was applied to the specimen before the start of the fatigue test. In the second, the specimen was stressed in the fatigue-testing machine for a predetermined number of cycles at one amplitude, and then carried to failure at a second amplitude. In this way, data have been provided on the effects of both static and dynamic stress, applied prior to the fatigue test, on the fatigue properties of the material.

Conventional repeated-bending fatigue-testing machines were employed.

(Continued on Page 18)

* Technical Report 1520, National Bureau of Standards, U. S. Department of Commerce, Washington 25, D. C.

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Effects of Prior—

(Continued from Page 16)

In these machines one end of the specimen is held fixed in a vice while the other end is deflected up and down by means of an adjustable, motor-driven eccentric and crank. The design of the specimen, however, was new and was found to have several advantages over the usual type. Another innovation was a jig which measured the specimen before testing and automatically located the point at which the stress in the specimen would be a maximum.

The static prestress studies were made with Alclad 24S-T sheet and all fatigue tests with this group of samples were operated in unidirectional bending; that is, the specimen was bent in only one direction from the "no load" position. First a sufficient number of specimens were tested without prestress to give the typical relationship between stress amplitude and number of cycles to fracture for the original material. Then a static load was applied to the remainder of the specimens before starting the fatigue test. In some cases the bending load in the fatigue test was in the same direction as the static load; in others these directions were opposite.

At the higher test stresses (25,000, 30,000, and 35,000 pounds per square inch), the effect of the static prestress was negligible. However, at the test stress of 20,000 pounds per square inch, there was an appreciable decrease in life for the specimens prestressed in the direction opposite to that of the subsequent fatigue stress. On the other hand, there was a slight increase in life for the specimens with a prior static stress in the same direction. The net result was a 10-to-1 difference in life between these two sets of specimens.

Dynamic Prestress Evaluated

The tests for evaluating the effect of dynamic prestress were made on specimens of bare 24S-T sheet. The fatigue

Corrosion News Deadline: 10th of Month PRECEDING Date of Issue

loading was applied in completely reversed bending. That is, the specimens were deflected equally to each side of the no-load position. The prestress amplitude was applied for a given number of cycles before the specimen was carried to failure at the test stress. Three values of prestress amplitude were used and four test stresses.

At the two higher prestress amplitudes (22,500 and 32,500 pounds per square inch) fracture occurred earlier in the prestressed samples than in the original material. It seems therefore that a portion of the fatigue life of the alloy is used up by the prior stress. Within experimental error it was found that this portion was approximately equal to the ratio of the number of cycles run at a given prestress to the number of cycles which will cause failure at that stress.

For the lowest prestress, however, (17,000 pounds per square inch) the behavior was entirely different. At a slightly higher test stress (20,000 pounds), there was a noticeable improvement in the life of the specimens. Two thousands cycles and 2,000,000 cycles of prestress produced an increase of more than 400 percent. Even at 20,000,000 cycles, the increase was of the order of 33 percent.

The immediate importance of this work is the possibility of improving the fatigue life of structural members by prestressing. Of more fundamental significance, however, is the aid it may offer toward determining the mechanism of fatigue failure in metals.

Corrosion Problems

E. A. TICE, Editor

Corrosion Engineering Section, The International Nickel Co., Inc., 67 Wall St., New York 5, N. Y.

Submit questions and answers for this column in duplicate to the editor. All questions become property of NACE. Questions and Answers may or may not be published under this heading, and may at discretion, be answered by mail directly. Answers to questions are solicited. Authors of questions will remain anonymous to readers while authors of answers may remain anonymous if they request it.

QUESTION

No. 31—At a fueling station for diesel locomotives, the fuel oil is piped from a 20,000-gallon storage tank through 1800 feet of 6-inch steel pipe to the locomotive. Rust in this line breaks loose and is carried into the fuel tanks of the locomotive where it causes trouble by clogging filters. The oil remains in the line an average of four to eight hours.

Is there a method which can be used to prevent corrosion in the 6-inch line, which will not have an adverse effect on the fuel? If not is there an economical material which can be used in place of steel for this pipe line?

ANSWER

The use of an inhibitor, Santolene C, should be a positive economic answer to this problem. In all probability the rust spreading to the locomotive fuel oil tanks comes not only from the pipeline itself but also from as far back as the 20,000-gallon storage tank. Since a rust inhibitor will only stop the formation of new rust, possibly even loosen pre-formed rust, it would be very desirable to clean both the tank and the pipeline before starting to use Santolene C. Once the system is cleaned, however, it can be protected both easily and economically by the addition of Santolene C either directly to the storage tank or as the fuel is being pumped into the storage tank. The further back in the system Santolene C is introduced the greater will be the extent of the protection.

While it is relatively simple to clean out the 20,000-gallon tank it might be considerably harder to clean out the pipe, since it is likely the concern is not equipped with normal pipeline scrapers. In lieu of a good cleaning, it is possible a filter could be located at the discharge end of the pipe when the Santolene C treatment is started.

On the basis of our past experience, existing rust will be loosened and sent down the pipe for a short time. This can be readily removed by the filter. After a reasonable time, experience indicates filtration can be stopped. It is still desirable, however, to clean the storage tank.

As a final fact of interest we have run several engine tests in both gasoline and Diesel engines to determine if there is any effect on their performance using fuel treated with Santolene C. These tests show no difference between treated and untreated fuel.—James B. Irwin, Monsanto Chemical Co.

No. 39—In order to melt snow and ice on city streets and bridges, either

(Continued on Page 20)



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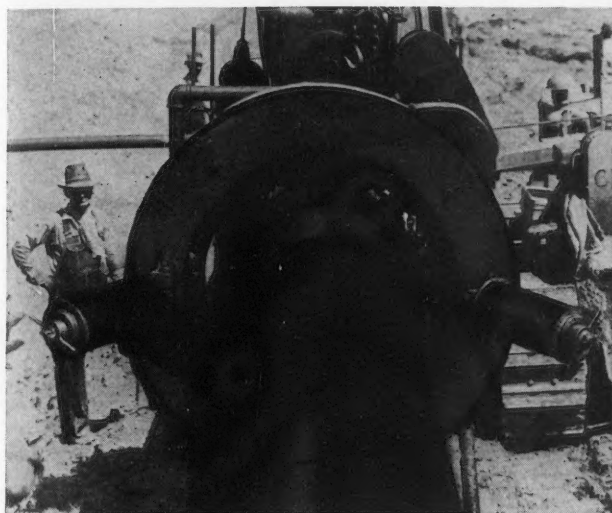
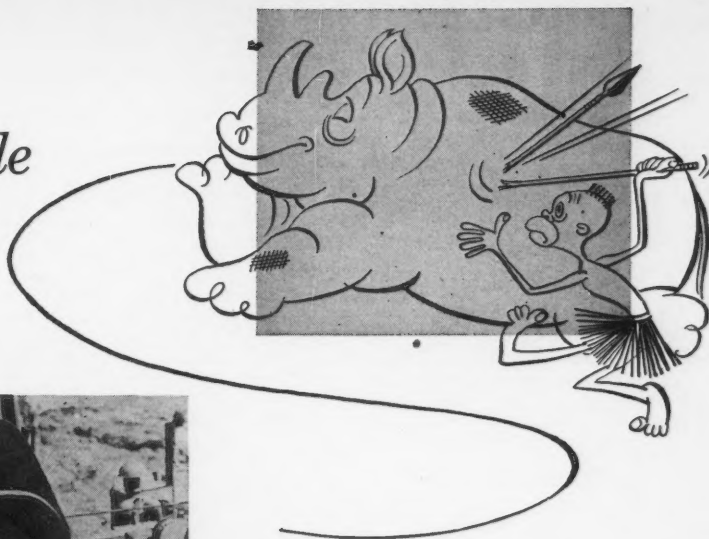
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Corrosion Problems—

(Continued from Page 18)

sodium chloride or calcium chloride is spread by means of automatic equipment conveyed on trucks. Is there an inhibitor which can be added to the salt to reduce corrosion of steel structures which become wetted by the slushy brine? If so, what is the minimum inhibitor concentration which will effectively stop corrosion?

ANSWER

A polyphosphate nitrite inhibitor can be used with sodium chloride for de-icing city streets. A minimum of 1 percent by weight of inhibitor must be used. However, this inhibitor has not been found to be successful with calcium chloride as the de-icing agent.—John A. Temmerman, City Chemist, City of Rochester, N. Y.

No. 56—How can mercury corrosion be identified on aluminum or admiralty tubes?

ANSWER

Mercury corrosion can be identified on aluminum or Admiralty tubes most readily through spectrographic analysis of the tube surface. In making such analysis it is important to have the specimen and the upper electrode properly lined on the optical axis of the spectrograph before starting the arc or spark. This precaution is very important because mercury is very rapidly volatilized during the first fraction of a second or seconds of testing.

Chemical means can also be used to identify the mercury present in or on the attacked metal. For example, a section of the affected area may be dissolved in nitric acid having a specific gravity of about 1.2, followed by boiling the resulting acid solution until it becomes sirupy, cooling, diluting with distilled water, then inserting a clean strip of copper. If any mercury is present in the solution, it will plate

out on the copper surface through a displacement reaction with the formation of a few pinpoints of bright liquid mercury if only a trace is present or the entire copper strip may be covered with mercury.

Microscopic examination of brass particularly will show intergranular penetration by mercury and considerable difficulty will be experienced in obtaining a good micro-specimen, since the mercury tends to smear on the specimen surface, due to the fact the grain boundaries are almost invariably wetted by liquid mercury. Bending of the affected tube is also helpful in revealing the presence of liquid mercury on the fractured surface.—C. L. Bulow, Bridgeport Brass Co., Bridgeport, Conn.

No. 63—What is known about the effect of solutions of sodium dichromate on Admiralty brass and other non-ferrous alloys, particularly from the standpoint of stress-corrosion cracking?

ANSWER

Comparative tests have been carried out in our laboratory on Admiralty brass and other brasses which have been previously immersed in sodium bichromate solutions containing some sulfuric acid solution, with the thought that a protective film of chromate might inhibit the action of ammonium hydroxide vapors when the specimens were stressed. These tests showed that no marked differences in results were obtained when dipped in various solutions prior to exposure in a stressed condition in ammonia vapors under the severe conditions of testing used. The ammonia vapors were obtained in a closed chamber by allowing ammonium hydroxide solution with a density of 0.90 to flow through the chamber.—C. L. Bulow, Bridgeport Brass Co., Bridgeport, Conn.

ASTM Meeting

The Fifty-Fourth Annual meeting of the American Society for Testing Materials will be held at Atlantic City, N. J. June 18-22.

Clippings on Corrosion

Extracted from Current Periodicals

INHIBITOR ADDED TO ICE-MELTING SALT

(From Brookfield, Mo. *News*, Feb. 9, 1951)

One part of Nalco inhibitor is being added to 100 parts of salt used for melting street and road ice to limit rusting of metals.

OBSOLESCENCE IS CHIEF LOSS IN MOTHBALLED SHIPS AND ORDNANCE

(From Tulsa, Okla. *World*, Feb. 18, 1951)

Obsolescence is the chief loss in the billions of dollars worth of ships and ordnance laid up after the end of World War II and now being put back into use. The process of "cocooning" guns has proved a failure because of damage to the barrier coating by ice and snow, the navy has discovered. This method is being considered only in the South.

Airplanes "cocooned" however, have suffered virtually no damage, the air force has discovered.

SALT-BASE ANTI-FREEZE LICENSING IS PROBED

(From Belle Plaine, Ia. *Union*, Jan. 31, 1951)

An investigation into the circumstances surrounding the licensing for sale and the cancellation of the license to sell of a salt-base anti-freeze has been investigated by the Iowa state legislature. Chemists have reported to a committee of the legislature that salt-base anti-freeze mixtures cause undue corrosion in the motors of automobiles.

HARDER STAINLESS IS WESTINGHOUSE CLAIM

(From Topeka, Kans. *Capital*, Feb. 19, 1951)

Stainless steels have been produced by a new low temperature treatment at Westinghouse research laboratories at Pittsburgh which are up to three times as hard as similar steels treated by conventional methods. The super-hardening is achieved by immersion in liquid nitrogen at 300 degree below zero F and rolling or forging at sub-zero temperatures. Besides increased mechanical strength the materials have improved corrosion resistance.

CORROSION IN ACTION STUDIED AT CHICAGO

(From Hutchinson, Kans., *News-Herald*, Mar. 6, 1951)

Dr. Howard T. Francis of the Illinois Institute of Technology reports a method of studying corrosion in process by analysis of electrical currents collected from a rotating cylinder by a stationary probe electrode. The probe consists of a plastic arm containing 11 silver wires placed very close to the submerged cylinder. The currents picked up by the wires are amplified and recorded.

(Continued on Page 22)

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Clippings on Corrosion—

(Continued from Page 20)

BIOLOGICAL PRODUCTION OF SULFUR IS WEIGHED

(From Houston, Texas, *Chronicle*, Mar. 5, 1951)

Speeding up production of sulfur through conversion of chemicals in waters by bacterial action is possible. British scientists are using varieties of sulfur-producing bacteria from all parts of the world in experiments at an artificially cultured lake in England. Large quantities of sulfur already have been produced.

CORROSION IN DRILLING COVERED AT SCHOOL

(From Wichita, Kans., *Beacon*, Mar. 4, 1951)

A school held at Cities Service Oil Company's camp at Chase, Kans., under Philip C. Blackburn, petroleum training specialists at the University of Texas, covered subjects under the title "Treating of Oil Field Emulsions." Included were treating oil to meet pipeline specifications, use of treaters, gun barrels, batch treating and control of corrosion.

CHROME PLATING METHOD WITHOUT COPPER, NICKEL

(From *New York Times*, Apr. 11, 1951)

Cleveland. R. T. Hendrich, president of the Wire Coating and Manufacturing Co. said he had developed a method of chrome plating without copper or nickel. Castings are given a bright zinc coating, a chromate bath, and then chrome plated.

ARSENIC ALLOY IN LEAD CABLES EXTENDS LIFE

(Albuquerque, N. M., *Tribune*, Mar. 8, 1951)

One tenth of one percent arsenic added to lead alloy cable sheaths of underground power lines gives them longer life, Prof. Curtis W. Dollins of University of Illinois claims.

END CONNECTIONS LIMIT ALUMINUM CABLE USE

(From *American Metal Market*, Mar. 23, 1951)

The automotive industry would use aluminum electrical cable if a satisfactory solution could be found to the corrosion of joints and end connections, Alfred L. Boegehold, head of the General Motors Corp. metallurgical department said.

CITY PONDERING PROTECTING NEW STEEL RESERVOIR

(From Fayetteville, Ark., *NW Ark. Times*, Feb. 26, 1951)

A method of protecting the inside of the city's new steel reservoir from rust and corrosion will be considered by city officials. The possibility of installing an electro-plate device designed to prevent the formation of corrosive chemicals within the tank has been discussed.

CORRODED GAS FITTINGS DESIGNATED LIFE HAZARD

(From Green River, Wyo., *Star*, Feb. 1, 1951)

Sections of corroded pipe fittings, elbows and other apparatus were shown members of the city governing body by

John Dankowski, in charge of Mountain Fuel Supply Co. in Green River. Mr. Dankowski lectured on the danger from improper gas connections. Gas company representatives said fumes escaping from the defective fittings were responsible for one death and near death to another.

CORROSION DAMAGE TO AUTOMOBILES EVALUATED

(From Arlington, Tex., *Journal*, Mar. 30, 1951)

W. G. Johnstone, Sinclair agent, speaking to 200 Sinclair Refining Co. dealers and agents said "Rust and corrosion cause over 35 percent of all repairs to (automobile) carburetor and fuel pumps."

MAGNESIUM ADVOCATED TO PROTECT RANGE BOILERS

(From Indianapolis, Ind., *Star*, Mar. 28, 1951)

Question—Can anything be done to prevent the rapid failure by corrosion of the ordinary galvanized range boiler? These failures occur in from two to five years and I am told that they are caused by an electrolytic action resulting from the use of brass and copper fittings. Formerly when galvanized pipe and fittings were used a range boiler life of 10 to 15 years was quite usual, but the hot water connections rapidly became clogged up by a kind of rusty sediment.

Answer—An anode rod sometimes called a magnesium rod—can be installed. This is coming into wide use and is quite effective in reducing corrosion. It has to be replaced in time because it eventually disintegrates. The maker of your water heater can give you the names of the makers of these rods.

FERTILIZER CORROSION

(From McPherson, Kans., *Republican*, Apr. 6, 1951)

Fertilizers are highly corrosive. Unless the fertilizer that remains in or on the machine is cleaned out carefully, it will cause heavy rust. Cleaning and flushing with kerosene is recommended.

NEW METAL ALLOY HAS CORROSION RESISTANCE

(From Mena, Ark., *Star*, Mar. 20, 1951)

Chemalloy Associates, Inc., Santee, Cal., claims a proprietary alloy it has developed never rusts or corrodes, is

self-lubricating and can be used as a welding agent for aluminum without flux.

PIPELINE FIRM AWARDED DAMAGES FROM ARKANSAS

(From Little Rock, Ark., *Gazette*, Mar. 20, 1951)

Arkansas Supreme Court increased by \$5000 a \$10,000 award to Magnolia Pipe Line Co. against the Arkansas Game and Fish Commission to offset increased costs the company is expected to incur as a result of the commission's creating Lake Conway, in Faulkner County, which covers six miles of the Magnolia line with water. The company contended the water would make maintenance of the line more difficult and costly.

ANCIENT'S METALLURGICAL SKILL EQUAL TO TODAY'S

(From *New York Herald Tribune*, Apr. 12, 1951)

Dr. Earle R. Caley, Ohio State University chemistry professor, told a dinner session of the 119th American Chemical Society meeting that his investigations show metals of the ancient Romans, Greeks and Egyptians were as pure as those produced today. The ancient Roman lead, he said, reached a purity of 99.95 percent.

LOW-COST SOLUTION TO CORROSION DISCUSSED

(From *New York Journal of Commerce*, Apr. 10, 1951)

Cleveland. Metal surfaces have been made impervious to corrosion by use of gas molecules, but the resistance is only temporary, according to Dr. Norman Hackerman, of the University of Texas, who presided over a symposium at the 119th National Meeting of the American Chemical Society. Attaching gas molecules to metal surfaces may be a low-cost solution to the corrosion problem.

BILL REGULATES TRUCKS CARRYING CORROSIVES

(From *New York Times*, Apr. 11, 1951)

Albany. Governor Dewey signed a bill providing, among other things, regulations for the transporting in motor vehicles of dangerous substances, such as inflammable liquids and gases, corrosive liquids, poisonous substances and radioactive material. Trucks carrying dangerous materials must be marked with placards, interstate trucks excepted.

NACE MEMBERS CHANGING STATUS

Notification to Central Office NACE of changes of membership status, including changes of address should be made personally by the member.

NACE is reluctant to make changes in membership records except when asked to do so by members themselves.

Please note also:

1. Active and junior memberships are non-transferable, because applications are signed personally by members, therefore
2. All persons wishing to become members of NACE must submit and sign personally an application containing a concise statement of qualifications and including the names of two NACE members in good standing as references.

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For Making Soil and Ground Resistance Measurements!

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MODEL 263

VIBROGROUND

Brance-Krachy is proud to offer the model 263 VIBROGROUND, designed expressly for making soil and ground resistance measurements in cathodic protection surveys or on finished installations. This instrument was especially designed to fit the needs of Corrosion Engineers after careful consultation with recognized leaders in the field. Emphasis has been placed on *light weight, portability and proper resistance ranges* for field work.

The instrument is capable of measuring *any* resistance value accurately from 0 to 1000 ohms, using either the two, three, or four electrode configuration. Of particular usefulness is the fact that average soil resistance at *any desired depth* may be determined merely by spacing the electrodes properly. The instrument always measures average soil resistance at a depth equal to the distance between the potential electrodes.

Readings are not affected by the resistance of auxiliary prods or leads. Polarization effects are reduced to a minimum. Stray AC or DC currents in the earth do not detract from its accuracy. No outside power source or mechanical operation is necessary. Its accuracy is not influenced by any jeweled meter; only by the accuracy of a calibrated resistor.



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- ★ **Powered by Flashlight Cells**
- ★ **Range:**
0-1; 0-10; 0-100; 0-1000 ohms
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THREE PERCENT
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Less than 10 lbs. with cover removed
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Soil resistance
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NACE

New Members and Changes of Address

(Changes through April 28, 1951)

CALIFORNIA

- FENTON, J. HARRY, Brance Krachy Co., Inc., 1036 Brent Ave., South Pasadena, Cal.
 GASTON, DON, Weber Showcase & Fixture Co., Box 2018, Terminal Annex, Los Angeles, Cal.
 GIBSER, RALPH, Rheem Manufacturing Co., 4361 Firestone Blvd., South Gate, Cal.
 MANAHAN, WILLIAM A., Long Beach Harbor Dept., Petroleum Engineering, 1333 El Embarcadero St., Long Beach 2, Cal.
 PRENDERGAST, JOHN P., California Water Service Co., 374 W. Santa Clara St., San Jose, Cal.
 RONAN, RICHARD J., South Chester Tube Co., 215 W. 7th, Los Angeles 14, Cal.
 SHIELDS, MORTON K., M. K. Shields Co., 463 S. Robertson Blvd., Beverly Hills, Cal.

CONNECTICUT

- JOHNQUEST, HARRY M., The Bristol Co., Waterbury 20, Conn.
 RASMUSSEN, LAURENCE M., Manning Maxwell & Moore, Inc., 11 Elias St., Bridgeport 2, Conn.

DELAWARE

- O'NEIL, HENRY J., JR., Gates Engineering Co., New Castle, Del.

ILLINOIS

- GOTSCH, L. P., American Can Co., Res. Dept., 11th Ave. & St. Charles Rd., Maywood, Ill.
 HALLDEN, JOHN T., Servissoft, Inc., 739 Twentieth St., Rockford, Ill.

KANSAS

- WAGGONER, VERBON E., Box 368, Goodland, Kan.

LOUISIANA

- COULTER, ELMER N., Cities Service Refining Corp., Basic Refinery Laboratory, Lake Charles, La.
 CUCULLU, LIONEL J., New Orleans Public Service, Inc., 317 Baronne St., New Orleans 9, La. (New corporate representative replacing Ireland, L. G.)
 GAEBNIE, ERNEST S., JR., Metal Goods Corp., 432 Julia St., New Orleans, La.
 MINTER, JAMES F., Shell Oil Co., Box 271, Donaldsonville, La.
 SMITH, WINSTON G., A. O. Smith Corp., 8309 Pritchard Place, New Orleans, La.

MARYLAND

- McCUSKER, WILLIAM A., Baltimore Transit Co., 1500 Washington Blvd., Baltimore, Md.
 STREEP, SAMUEL C., The Davison Chemical Corp., Baltimore 3, Md.

MASSACHUSETTS

- SWIFT, JOHN, Lever Bros. Co., 164 Broadway, Cambridge, Mass.

MICHIGAN

- BRINES, M. E., 1603 Crane Court, Midland, Mich.

NEW JERSEY

- ALLEN, EDWARD R., School of Chemistry, Rutgers Univ., New Brunswick, N. J.
 CLERMONT, WILLIAM L., Public Service Electric & Gas Co., 80 Park Place, Newark, N. J.
 DONOHUE, J. L., Inertol Co., Inc., 480 Frelinghuysen Ave., Newark, N. J.
 MUNRO, JOHN D., 2588 Mountain Ave., Scotch Plains, N. J.
 NAPACK, MARVIN, Air Reduction Corp., Res. & Dev. Lab., Murray Hill, N. J.
 TUHY, MIRKO J., 51 Helen St., Fanwood, N. J.

NEW MEXICO

- COCKE, WILLIAM J., 1500 Ridgcrest Dr., Albuquerque, N. M.

NEW YORK

- CARPENTER, HOWARD B., Esso Standard Oil Co., 15 West 51st St., New York 19, N. Y.
 FERRARO, ANTHONY, 85-89 87th St., Woodhaven 21, N. Y.
 HILTON, ROBERT W., 1013 Rottkamp St., Valley Stream, Long Island, N. Y.

- LAWLESS, SYDNEY, Food Machinery & Chemical Corp., Westvaco Chemical Div., 405 Lexington Ave., New York 17, N. Y.
 MACCORKLE, DANIEL S., D. S. MacCorkle Co., 50 Church St., New York City, N. Y.
 NILSON, WESLEY G., Ebasco Services, Inc., 2 Rector St., New York 6, N. Y.
 OATES, JOHN J., New York Testing Laboratories, 80 Washington St., New York, N. Y.
 OLMSTEAD, PHILIP J., Goulds Pumps, Inc., 240 Fall, Seneca Falls, N. Y.
 PARKER, ROBERT B., American Brake Shoe Co., 230 Park Ave., New York 17, N. Y.
 WRIGHT, CHARLES L., Shell Chemical Corp., 50 W. 50th St., New York 20, N. Y.

NORTH CAROLINA

- TEEL, RODNEY B., 31 Lee Drive, Lake Forest, Wilmington, N. C.

OHIO

- CASTER, ARTHUR D., 38 Arcadia Place, Cincinnati 8, Ohio.
 DAYMUDE, JOHN F., 3715 Highpoint Ave., Cincinnati 11, Ohio.
 GEHRES, H. A., The Cooper-Bessemer Corp., Mount Vernon, Ohio.
 JENSS, ALFRED D., Ampco Metal, Inc., Rose-lawn Center Bldg., Reading & Section Rds., Cincinnati 37, Ohio.
 PETROV, L. A., National Distillers Products Corp., 1265 Section Rd., Cincinnati 37, Ohio.
 THIES, H. R., The Goodyear Tire & Rubber Co., Inc., Chemical Div., 1452 E. Archwood, Akron, Ohio.

OKLAHOMA

- NODURET, HARRY M., Consolidated Gas Utilities Corp., Box 303, Weatherford, Okla.
 VENEIGH, LEROY J., 1201 S. W. 41st St., Oklahoma City, Okla.

PENNSYLVANIA

- KELLY, BERNARD J., United States Steel Co., 525 William Penn Place Bldg., Pittsburgh 30, Pa.
 MACE, A. E., Harco Corp., 850 North Ave., R. D. #3, Media, Pa.
 PINKERTON, HARRY L., Saran Lined Pipe Co., 701 Investment Bldg., Pittsburgh 22, Pa.
 STEVENS, CHAPIN E., General Aniline & Film Corp., 22 Center Square, Easton, Pa.

TEXAS

- ABDALLA, ABRAHAM JR., 2069 Southgate Blvd., Houston, Texas.
 ANDERSON, VICTOR A., University of Houston, 3801 Cullen Blvd., Houston, Texas.
 ARMOUR, GILBERT A., 1532 Nashua, Houston, Texas.
 CHARAT, HANOH, Sola Catalytic Co., 520 Browder, Dallas, Texas.
 GARTNER, FRED W., JR., F. W. Gartner Co., 3805 Lamar, Houston, Texas.
 GOELZENLEUCHTER, ALVIN H., 3211 Elser, Houston, Texas.
 HAMMER, WILLIAM A., Emasco Derrick & Equipment Co., P. O. Box 1289, Houston 2, Texas.
 LEVY, MAX M., JR., Tuboscope, P. O. Box 8295, Houston, Texas.
 McANINCH, DON L., Box 314, Pearland, Texas.
 MOORE, EARL D., 7427 Brockley, Houston 17, Texas.
 NOVAK, GEORGE W., JR., 2622 Greenbriar, Houston 6, Texas.
 PICKARD, W. B., JR., Earl Paint Corp., Texas Div., 2502 Robinhood, Houston, Texas.
 POOLE, ROBERT W., 3812 Roseland, Houston, Texas.
 QUINN, JOHN A., 511 Drew St., Houston, Texas.
 ROESLER, BERNARD R., Box 824, Rosenberg, Texas.
 STOVALL, JOSEPH H., 405 Bayland, Houston 9, Texas.
 STUART, JACK L., Sola Catalytic Co., 520 Browder, Dallas, Texas.
 TOTAH, NADIM, 1121 La Branch St., Houston 3, Texas.
 UNGER, JULIAN H., Tuboscope, P. O. Box 8295, Houston, Texas.
 VOIGHT, RICHARD A., Trailer Village, #43, University of Houston, Houston 4, Texas.

UTAH

- JONES, HENRY P., J. Henry Jones Co., 120 Apricot Ave., Salt Lake City, Utah.

VIRGINIA

- BOULWARE, ROBERT C., JR., E. I. du Pont de Nemours & Co., Waynesboro Works, Waynesboro, Va.
 HACKNEY, R. PEELE, The American Tobacco Co., Res. Lab., P. O. Box 4178, Richmond 24, Va.
 UNGER, LEWIS C., Commonwealth Natural Gas Corp., 219 E. Broad St., Richmond, Va.

WISCONSIN

- CHARTER, KENNETH F., A. O. Smith Corp., Milwaukee 1, Wis.

FOREIGN

- GATTENMEYER, JOHN L., Shell Oil Co., Box 100, Calgary, Alberta, Canada.
 MOLNAR, ERIC G., Texas Petroleum Co. (Ven. Div.), Apdo 267, Caracas, Venezuela.

CHANGES OF ADDRESS

(Old address follows new in parenthesis)

CALIFORNIA

- FARWELL, MILO S., Bethlehem Pacific Coast Steel Corp., Box 3494, Rincon Annex Station, San Francisco, Cal. (Bethlehem Pacific Coast Steel Corp., San Francisco, Cal.)
 PATTON, ARTHUR L., 2712 Tyler St., Long Beach 10, Cal. (Long Beach Naval Shipyard, Seaside Blvd., Long Beach 2, Cal.)

DELAWARE

- ADAMS, HENRY W., 23 York Rd., Deerhurst, Wilmington 3, Del. (Amercoat Corp. 29 New York Ave., Newark 5, N. J.)

FLORIDA

- LEWIS, ROBERT H., 708 N. E. 2nd St., Fort Lauderdale, Fla. (Robert H. Lewis, Inc., 1227 Las Olas Blvd. (East), Fort Lauderdale, Fla.)

GEORGIA

- PARKER, IVY M., Plantation Pipe Line Co., Box 423, Bremen, Ga. (Plantation Pipe Line Co., Bremen, Ga.)
 TRAPP, RAYMOND F., Midwestern Engine & Equipment Co., 3431 Sherman Rd., Hapeville, Ga. (Midwestern Engine & Equipment Co., 105 N. Boulder, Tulsa, Okla.)

ILLINOIS

- CONVERSE, E. M., Dearborn Chemical Co., Merchandise Mart Plaza, Chicago 54, Ill. (Dearborn Chemical Co., 310 S. Michigan Ave., Chicago 4, Ill.)
 PETERKIN, DON W., 3431 S. Ashland Ave., Chicago 8, Ill. (Metallizing Engineering Co., Inc., 322 W. Washington, Chicago 6, Ill.)
 SCHMIDT, BURTON J., 220 Center Park Ave., Wilmette, Ill. (The Tapecoat Co., 1521 Lyons, Evanston, Ill.)
 SMITH, CARL B., Dearborn Chemical Co., Merchandise Mart Plaza, Chicago 54, Ill. (Dearborn Chemical Co., 310 S. Michigan Ave., Chicago 4, Ill.)
 SVRCEK, JOSEPH C., Dearborn Chemical Co., Merchandise Mart Plaza, Chicago 54, Ill. (Dearborn Chemical Co., 310 S. Michigan Ave., Chicago 4, Ill.)
 WILKES, JOHN F., Dearborn Chemical Co., R. R. Dept., Merchandise Mart Plaza, Chicago 54, Ill. (Dearborn Chemical Co., R. R. Dept., 310 S. Michigan Ave., Suite 1912, Chicago 4, Ill.)

MASSACHUSETTS

- RODDY, LT. DAVID F., 0465557, Headquarters, Army Security Agency School, Fort Devens, Mass. (Texas-New Mexico Pipe Line Co., 708 East Main, Denison, Texas.)

MICHIGAN

- MORSE, ARLEY EDWIN, Route #1, Box 339, Coloma, Mich. (The Dow Chemical Co., 135 S. LaSalle, Chicago 3, Ill.)

MISSOURI

- REID, KEITH K., Aluminum Ore Co., 1500 Mississippi Valley Trust Bldg., St. Louis 1, Mo. (Aluminum Co. of America, New Kensington, Pa.)

NEW JERSEY

- AYRES, ALBERT L., New Jersey Bell Tel. Co., 281 Washington St., 8th Floor, Newark 2, N. J. (New Jersey Bell Tel. Co., 281 Washington St., 4th Floor, Newark 2, N. J.)
 SERVEN, EDWARD J., JR., 18 Arlington Ave., Clifton, N. J. (200 Hazel Rd., Clifton, N. J.)

NEW YORK

- THORNBURG, JOSEPH E., Hooker Electrochemical Co., 838 Orchard Parkway, Niagara Falls, N. Y. (Hooker Electrochemical Co., P. O. Box 344, Niagara Falls, N. Y.)

OHIO

- BUTLER, EDWARD B., 3219 Middlesex Drive, Toledo 6, Ohio (525 Knollwood Dr., Dora Lee Apts., Apt. 102, Falls Church, Va.)
 CAPAUL, R. W., Glass Fibers, Inc., 1819 Madison Ave., Toledo 2, Ohio (Glass Fibers, Inc., Waterville, Ohio.)
 GREGORY, MILTON W., Glass Fibers, Inc., 1810 Madison Ave., Toledo 2, Ohio. (Glass Fibers, Inc., Waterville, Ohio.)

(Continued on Page 25)

NACE New Members—

(Continued from Page 24)

OKLAHOMA

BLAIR, JOHN V., Ambassador Hotel, Tulsa 1, Okla. (Albany Hotel, Tulsa, Okla.)
 DANNE, HERBERT J., Elder & McNulty, 1120 N. Braden, Tulsa, Okla. (Pipeline Maintenance Corp., Box 1424, Tulsa, Okla.)
 GETTYS, WILBUR H., c/o L. A. Hugo, Phillips Petroleum Co., Engineering Dept., Bartlesville, Okla. (Phillips Petroleum Co., Engineering Dept., Bartlesville, Okla.)
 SHOCK, D. A., Prod. Lab., Continental Oil Co., P. O. Drawer 1267, Ponca City, Okla. (Continental Pipe Line Co., P. O. Drawer 1267, Ponca City, Okla.)

OREGON

BAUNACH, ROBERT P., JR., 4950 S. W. Barbour Blvd., Apt. E7, Portland 1, Ore. (2437 N. E. Hoyt St., Apt. 8, Portland 12, Ore.)

PENNSYLVANIA

HONEN, RAYMOND B., U. S. Steel Research Lab., 234 Atwood St., Pittsburgh 13, Pa. (Case Institute of Technology, University Circle, Cleveland 6, Ohio.)
 RINGER, FRANCIS, 370 Trevor Lane, Bala-Cynwyd, Pa. (Texas Eastern Transmission Corp., P. O. Box 32, Downingtown, Pa.)

TEXAS

DAY, STEPHEN D., S. D. Day Co., 1973 West Gray Ave., P. O. Box 13126, Houston 19, Texas (S. D. Day Co., 2017 West Gray Ave., Houston 19, Texas.)
 GUMM, HOWARD W., 1347 Munger, Houston 23, Texas. (Houston Industrial Gas Co., 215 N. Roberts, Houston, Texas.)
 HAAS, C. A., Wyatt Metal & Boiler Works, P. O. Box 3052, Houston 1, Texas. (Wyatt Metal & Boiler Works, 4152 Tennyson, Houston, Texas.)
 PERKINS, WENDELL L., 411 Marion Dr., Longview, Texas. (Ebasco Services, Inc., 2 Rector St., New York 6, N. Y.)
 VOGEL, ALFRED J., 1700 Harvard St., Midland, Texas. (P. O. Box 296, Andrews, Texas.)
 WINEGARTNER, E. C., 3417 1/2 Michigan St., Baytown, Texas. (WINEGARTNER, EDGAR C., The Brush Beryllium Co., Luckey, Ohio.)
 WRIGHT, RANDOLPH E., Box 827, El Campo, Texas. (The Texas Co., P. O. Box 2332, Houston, Texas.)

WISCONSIN

FRIEDEN, ALEXANDER, Pabst Laboratories, 1037 W. McKinley Ave., Milwaukee 3, Wis. (Pabst Brewing Co., 917 W. Juneau Ave., Milwaukee, Wis.)
 McCLINTOCK, ROBERT D., 282 West Main, Room 206 Emerson Bldg., Waukesha, Wis. (Michigan-Wisconsin Pipe Line Co., 500 Griswold St., Detroit 25, Mich.)

FOREIGN

DAVIS, RUSSELL L., 4114 W. 10th St., Vancouver, B. C., Canada. (Bahrain Petroleum Co., Awall, Bahrain Island, Persian Gulf.)

NEW CORPORATE MEMBERS

The following firms have become corporate members of the National Association of Corrosion Engineers since publication of a list in the May, 1951 issue:

AMERICAN BRAKE SHOE CO.
 New York, N. Y.

Robert B. Parker, Representative

THE BABCOCK & WILCOX CO.

New York, N. Y.

Dr. F. Eberle, Representative

FOOD MACHINERY & CHEM. CORP.

Westvaco Chemical Division

New York, N. Y.

Sydney Lawless, Representative

GOODYEAR TIRE & RUBBER CO., INC.

Chemical Division

Akron, Ohio

H. R. Thies, Representative

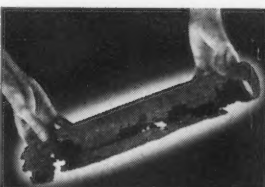
NATIONAL DISTILLERS PROD. CORP.

Cincinnati, Ohio

L. A. Petrov, Representative



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PLASTIC TAPE PROTECTS BURIED PIPE AGAINST RUST, EARTH ACIDS, ALKALIES

Don't let moisture and caustic minerals eat away your maintenance budget! Just wrap "Scotch" Electrical Tape No. 22 around buried pipes, connectors, elbows—any metal you want to keep rust-free for a long, long time. Easy to apply... and no hazardous hot coatings to endanger your workmen. Patching and repairing are cleaner, faster too.

"Scotch" Electrical Tape No. 22 has the same polyvinyl chloride backing that has been successfully used for 15 years on underground electric cables. Now your line goods get the same dependable protection.

Give it a try today. See how this remarkable tape stretches to conform to odd shapes, how it sticks tight without any activation. Available in 36-yard rolls, 1/2 inch to 4 inch standard widths.

Quick Facts about

"SCOTCH" Electrical Tape No. 22

- STRETCHY—moulds to any surface.
- RESISTS—water, oil, alkalies, most acids.
- HIGH DIELECTRIC—over 10,000 volts.
- TOUGH—plastic resists abrasion.



The term "Scotch" and the plaid design are registered trade-marks for the more than 100 Pressure-sensitive adhesive tapes made in U.S.A. by MINNESOTA MINING & MFG. CO., St. Paul 6, Minn.—also makers of "Scotch" Sound Recording Tape, "Underseal" Rubberized Coating, "Scotchlite" Reflective Sheeting, "Safety-Walk" Non-Slip Surfacing, "3M" Abrasives, "3M" Adhesives. General Export: Minn. Mining & Mfg. Co., International Division, 270 Park Avenue, New York 17, N. Y.

NEW PRODUCTS — Materials — Service — Literature

Mutual Chemical Company has completed a new chromium chemical plant to increase its production of sodium bichromate and other chromium compounds. Located on Baltimore harbor, near adjoining facilities constructed previously, the new plant is expected to add substantially to Mutual's output.

The Properties and Methods of Working Seamless and Welded Tubes of the B & W Stainless Croloys, Technical Bulletin 1B, 104 pages, leather-bound, 8 x 5 inches, is offered free on request by Babcock & Wilcox Tube Company, Beaver Falls, Pa. Intended for engineers, designers and fabricators, it is designed to serve as a guide in choosing proper materials and as a help in planning conversion of stainless steel tubing into finished products. It deals with methods of manufacture and inspection, corrosion and oxidation resistance, methods of working and fabrication and contains tables of technical data for eight different types of stainless Croloys, covering physical and mechanical properties and processing data. Temperature and lineal conversion tables also are included.

"The Facts About Clean Oil," a 16-page booklet giving information on oil purification methods is available from Honan-Crane Corp., 33 Madison Ave., Lebanon, Ind.

Synthetic Rubber based corrosion control coatings are described in a pamphlet by Casey & Case Coating Co., P. O. Box 151, Maywood, Cal. Machinery and dampwall enamels, cement floor finishes and stucco-masonry coatings are covered.

Determination of Current Requirements for Cathodic Protection by Marshall E. Parker, consulting engineer, printed in *World Oil*, November, 1950, has been reprinted by Dowell Incorporated.

Water sampling and gauging methods are referred to in the discussion of "Gauging and Sampling Water Borne Wastes" by Charles F. Hauck, of Hall Laboratories, Inc. in *ASTM Bulletin* December, 1949. Reprints of the discussion are available on request from Hagan Corp., Hagan Bldg., Pittsburgh, Pa. The techniques available and automatic equipment designed to provide intermittent or continuous information on the characteristics of effluent are increasingly important to plant managers, the company states, as a result of the growing public recognition of the necessity for preventing stream contamination and the growing number of laws regulating effluent discharge.

Uses of Cast Monel are described in a reprint "Uses Broaden for Cast Monel" available from Cooper Alloy Foundry Co., Hillside 5, N. J.

Aluminum Foil up to 44 inches wide will be produced by a 100,000-square-foot plant erected at Jackson, Tenn., by

Aluminum Foils, Inc., substantially owned by Swiss Aluminum Company of Lausanne and Neuhausen, Switzerland.

Silver-Clad Steel, a product of Rolled Plate Division, American Silver Co., Flushing, N. Y., is available in widths up to four inches and thicknesses down to .005-inch in any required temper. It is being manufactured in various silver-to-steel thickness ratios and rolled and slit to commercial or precision tolerances. The material may be used as a substitute for brass, nickel-silver and other restricted metals subject to NPA Order M-47. The material is clad, not electroplated.

Vinylite acetate resins are described in a 28-page booklet published by Bakelite Company, a Division of Union Carbide and Carbon Corp., Dept. 1503, 300 Madison Ave., New York 17, N. Y. The booklet describes the advantages and limitations of many types, gives table and text technical data on solution viscosity, toughness, film strength and compatibility and softening temperatures. Acetate resins, alcohol-acetate resin solutions and acetate resin dispersions are discussed with particular reference to their inherent bonding qualities.

Fence-Bond, an aluminum paint recommended by manufacturers The Skybrite Co., 3125 Perkins Ave., Cleveland 14, Ohio, for painting over rusted chain-link fences retains its elasticity and penetrates every joint.

Cincinnati Cleaning and Finishing Machinery Co., Schmidt Bldg., Cincinnati 2, Ohio, has developed a new machine for application of rust-preventive coatings. It is especially designed for application of government specification No. AXS-673 Corrosion Preventive Compound.

India Paint and Lacquer Co., Los Angeles, Cal., has become a wholly-owned subsidiary of American-Marietta Company.

Cost Elements in Painting Steel Transmission Towers, a pamphlet consisting of material adapted from the Joseph Dixon Crucible Co., Jersey City 3, N. J. handbook "Transmission Tower Painting" is available on request by those who can use an analysis of cost factors for painting structures of this type. Tables and text give approximate costs of painting steel transmission towers.

Tapecoat Company, Evanston, Ill., has named Middle West Coating and Supply, Tulsa, Oklahoma, distributor of its products.

Dowell Incorporated has reprinted "Combating Corrosion in a Chemical Plant With Magnesium Anodes," by Oliver Osborn, from *Corrosion*, Vol. 7, No. 1, January, 1951.

Alox Corporation, 3953 Buffalo Ave., Niagara Falls, N. Y., has published a technical bulletin on a new oil-soluble rust inhibitor, L-1673 which the company says protects metals from corrosion ten to fifteen times longer than previous formulations made by Alox. The polar compounds in the material adhere tenaciously to metal surfaces, the company says, bond the oil to the surface and possess the advantage over corrosion preventive films that dry hard in that while they are as easily applied they are more easily removed. The material is recommended for protecting metals during fabrication or storage of transoceanic shipment.

Dearborn Chemical Company's Chicago office is now located at Merchandise Mart Plaza, Chicago 54, Ill.

Earl Paint Corp., Utica, N. Y., has opened a division office at 2502 Robinhood Road, Houston. W. B. Pickard, Jr., has been named Texas Division Manager. The company's principal product is "Erkote" Mastic.

Scott & Williams, Inc., will manufacture the "Hydropulse" pump, useful in pumping chemicals, abrasives and corrosives.

Alkaloy 550, a high solids liquid which is converted at time of use into a jet black resilient solid is available in small amounts for experimental purposes and in unlimited quantities with proper priority from Atlas Mineral Products Co., Mertztown, Pa. The material, based on furfuryl alcohol, overcomes deficiencies of similar materials in that it retains inherent flexibility, the company says.

Berkeley Scientific Corp., Richmond, Cal., has named John A. Green Co., 6815 Oriole Drive, Dallas, Texas, its representative for electronic instruments.

Silicated Rubber Coat Exterior Finish is the name of a ready-mixed coating claimed by the manufacturer to have the ability to bridge hairline cracks and act as a filler and finish coat combined. The material is made by Wilbur & Williams Co., 130 Lincoln St., Boston 35, (Brighton) Mass.

Westinghouse Film Catalogue, listing 72 sound films available for use for transportation charges only by social, professional and business groups is available on request from Westinghouse Electric Corp., Box 2099, Pittsburgh 30, Pa.

Vacuum Calculations may be made with the slide-rule-type calculator issued by F. J. Stokes Machine Co., Philadelphia, Pa. It will determine needed pump capacity to evacuate a given volume in a given time and time required to reach a specified vacuum in a given volume with a pump of known capacity, among other similar chores.

Safety Rules for Pipe Line Construction, a pocket-sized manual for its em-

(Continued on Page 27)

New Products—

(Continued from Page 26)

ployes is issued by H. C. Price Co. B. G. Pierce is director of the safety department.

Super Rustfree Steel Alloys, products of the Uniworld Research Corp. of America, 1302 Ontario St., Cleveland 13, Ohio, do not contain cobalt, columbium, titanium or zirconium and use less nickel than alloys of competitive performance. Manufacturers state material has high corrosion resistance especially against sulfuric acid.

Five Types of pipe line coatings and three kinds of pipe wrap are being marketed by The Trenton Corp., Wolverine Bldg., Ann Arbor, Mich. Coatings are: Innercoat, applied next to pipe, consisting of mineral waxes and an inhibitor, is applied at 250 to 450 degrees F. Trenton Outercoat is applied at 300 to 450 degrees F over wraps. Primecoat is applied cold, and contains an inhibitor and a bonding agent. Trenton Graycoat, cold-applied for patching and reconditioning, is a blend of high-melting-point petroleum products with an inhibitor combined and remains soft. Redcoat, cold-applied to pipe or wrapping, recommended for field joints and patching, hardens into a film on the outside but remains soft and flexible beneath. The three wraps, Mono-Ply, a continuous thin sheet of tough opaque plastic, is designed for hand or machine application. It is resistant to water, vapor and most gases and highly resistant to electrical currents. Duo-ply is a combination wrapper consisting of a heavy film of inert plastic hot calendered into a sheet of asbestos felt that has been saturated with mineral wax. Tri-Ply, an aluminum core wrapper for use with hot or cold coatings, consists of a sheet of aluminum foil with a layer of plastic permanently extrusion-bonded to each side. All wrappings are under the trade name "Mummy Wrap."

Ace-Saran and **Ace-Parian** plastics are described in a new bulletin available from American Hard Rubber Co., 11 Mercer St., New York 13, N. Y. Text and tables give information on chemical resistance, bursting and working pressures, standard sizes, weights and include information on fabrication of systems using the plastics.

Service and Facilities for parallel light transmission and haze determinations on plastic materials following exposure in Southern Florida in accordance with Fed. Spec. LP-406a Method 3021 and Spec. MIL-P-6887 and in conformance with ASTM D1003-49T and other specifications are available now from South Florida Test Service, 4201 N.W. Seventh St., Miami 34, Fla. Installation of a Hunter Pivotal-Sphere Hazemeter and Photometric unit, as well as additional instrumentation is announced for testing plastics, textiles, paints, rubber, etc., to sunlight, direct, under glass and filters, and weathering to inland or salt atmospheres, tidalwater, total immersion and special tests.

Notices of meetings to be held by NACE subdivisions will be carried in the "NACE Calendar" if received in time.

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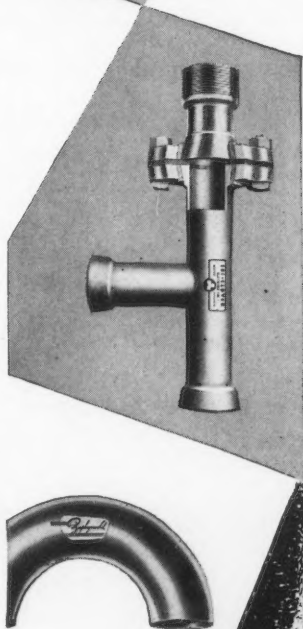
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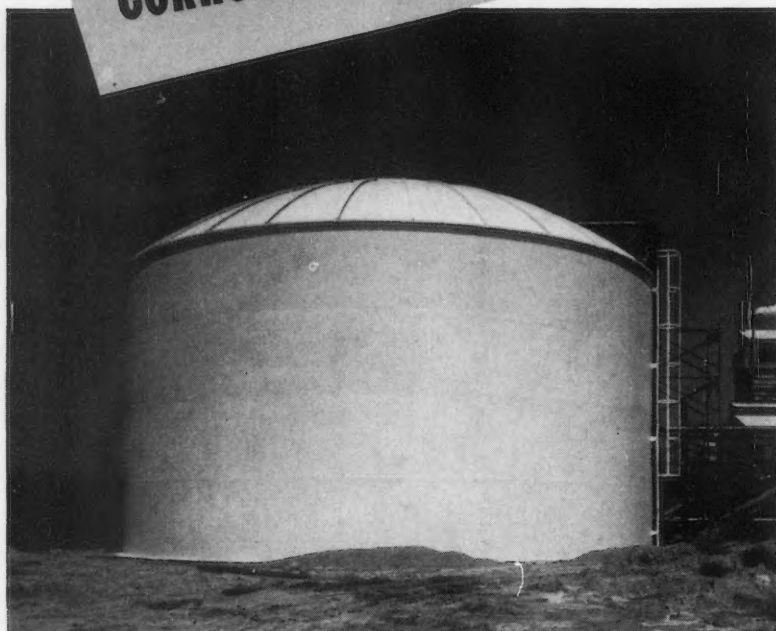
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FACILITIES for storing corrosive liquids can be completely efficient only when they are built of the proper metals. That's why the Chemical Division of the Lion Oil Company stores ammonium nitrate solution in a Horton stainless-clad steel tank at its plant in El Dorado, Arkansas.

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PERSONALS

Dr. George O. Curme, Jr. has been elected vice-president in charge of research of Union Carbide and Carbon Corp. Since 1948 he has been vice-president in charge of chemical research for the corporation and was for many years a vice-president of Bakelite Company and Carbide and Carbon Chemicals Company. Dr. Curme is said to be the first in the United States to develop the chemistry of the aliphatic compounds. **Morse G. Dial** has been elected executive vice-president of Union Carbide and Carbon Corp.

Hill, Hubbell and Company sales personnel attending a 3-day meeting at Hotel Statler, Cleveland were Earl Brightbill, assistant superintendent of the Lorain plant; R. A. McCarthy, Dallas salesman; M. M. Bowen, manager; Bryan Patterson, Salt Lake City salesman; J. C. Maxwell, superintendent of the Girard plant; C. D. Cobbett, Pittsburgh salesman; Norman Atchison, Cleveland office; R. J. Young, New York salesman; C. L. McGarvey, general superintendent; Lee Maffei, assistant superintendent Girard plant; George Hudock, Chicago salesman; Glenn Kilian, Cleveland office and Lee Hamilton, superintendent Lorain plant.

D. B. Bishop is new manager of Dearborn Chemical Co. Pittsburgh office, succeeding **J. A. Crenner**, retired.

Glenn N. Hunolt has been named district manager of the H. M. Harper Co., Morton Grove, Ill., with headquarters at St. Louis, Mo.

Ray Oster, with offices at Los Angeles, will handle sales of Atlas Mineral Products Co., corrosion resistant cements in the Los Angeles area. **Hugh G. Lawson** will handle jointing materials sales for the same area.

Claude E. Spencer, for 23 years with Sinclair Pipe Line Company and more recently with Keyes Tank Company, Casper, Wyoming, has joined the Natasco Company, Tulsa, Okla. Mr. Spencer is an authority on welding.

Lawrence J. Gorman, formerly engineer in charge of electrolysis studies and corrosion control for the Consolidated Edison Company of New York, long active in the National Association of Corrosion Engineers and until recently a director, is now affiliated with Robin Beach Engineers Associated, 32 Court St., Brooklyn 2, N. Y., as consultant.

Stuart H. Levison has been elected vice-president in charge of zinc and coal operations by American Smelting and Refining Co.

Elmer J. Nooter, president of Nooter Corp., St. Louis, died April 14, age 42. Robert J. Ryan, formerly executive vice-president, was elected to succeed Mr. Nooter.

David W. Peake is now with S. D. Day Company, Houston, Texas.



Corrosion Abstracts

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* PAGINATION OF CORROSION ABSTRACTS

Two numbers appear on each page of Corrosion Abstracts. The number in the upper outer corner is for page sequence within the issue only. The number in the lower outer corner, which is followed by the letter "a," denoting "abstracts," is for the convenience of those who bind Corrosion Abstracts by volumes. Because both numbers appear on each page and because it is believed indexing by the volume serial number will be more useful, the "Index to Corrosion Abstracts" is keyed to the number in the lower outer corner of each page followed by the letter "a."

GENERAL

• Miscellaneous

1.1
American Society for Metals. ASM-SLA Metallurgical Literature Classification. Prepared by a Joint Committee of the American Society for Metals and the Special Libraries Association. 11 x 8½ in. Pp [iv] + 49. 1950. Cleveland 3, Ohio: The Society, 7301 Euclid Ave. (\$1.00.)—MA.

• Importance

1.2, 1.7
Corrosion Mitigation Discussed at United Nations Meet: Systematic Research Urged by Speakers as Means of Reducing Huge Economic Losses. W. Beck. *Corrosion* (News Section), 6, No. 4, 19-21 (1950) Apr.

Review of some papers read at United Nations Conference on Conservation and Utilization of Resources. Includes papers by Vernon (see Note No. 2125/1949); Evans (Note No. 2367/1949); J. E. Carriere and C. A. Lobry de Bruyn on the cost and benefits of conservation of cast iron and steel pipe lines by control of corrosion; G. Chaudron on conservation of metals by corrosion control; M. Purbaix on the International Joint Commission for studying problems concerned with the operation of long-distance high-voltage transmission lines.—BNF.

• Organized Studies

1.7, 6.3, 7.2, 4.6
Copper Water Pipes: Result of B.N.F.M.R.A. Investigation on Corrosion. British Non-Ferrous Metals Research Association. *B.N.F. Misc. Pubn.* 420, Feb., 1950, 4 pp.

This is a short statement of the results of BNFMA investigations. It is found that the occasional pitting which occurs in copper cold-water pipes arises from the carbonaceous films sometimes produced on the pipes during manufacture. The occurrence of these films can be prevented and the pitting thus avoided. Copies of this statement are available.—BNF.

• Fundamentals

1.8, 4.3, 6.3, 1.3
Radiographic Proof of the Direct Oxidation of Platinum. (In German.) Rudolfo H. Busch. *Zeitschrift für Naturforschung*, 5b, 130-132 (1950) Apr.-May. Literature on the above is reviewed, showing the show information of PtO₂ and Pt₂O₃ under different conditions. Data are tabulated. 16 ref.—BLR.

1.8, 2.3, 6.4
The Oxidation of Vapor-Deposited Aluminum-Magnesium and Aluminum-Silver Alloys in Vacuum. II. (In German.) A. Boettcher. *Zeitschrift für angewandte Physik*, 2, 249-51 (1950) June 15.

The above was studied from 350 to 900°C and at a very low pressure in order to reveal the structure of very thin oxide films. Electron-diffraction tech-

PRIMARY SOURCES OF ABSTRACTS PUBLISHED IN CORROSION

AER—Aeronautical Engineering Review, Institute of Aeronautical Sciences, Inc. 2 East 64th St., New York 21, N. Y.

ALL—The Abstract Bulletin, Aluminum Laboratories, Ltd. P. O. Box 84, Kingston, Ontario, Canada.

AWWA—Journal, American Water Works Association. Amer. Water Works Assoc., 500 5th Ave., New York 18, N. Y.

BL—Current Technical Literature, Bell Telephone Laboratories, Inc., Murray Hill, N. J.

BLR—Battelle Library Review, Battelle Memorial Institute Library, 505 King Ave., Columbus, Ohio.

BNF—Bulletin; British Non-Ferrous Metals Research Association, 81-91 Euston St., London NW 1, England.

CALCO—Calco Chemical Division, American Cyanamid Corp. Bound Brook, New Jersey.

CE—Chemical Engineering, McGraw-Hill Publishing Co. 330 W. 42nd St., New York 18, N. Y.

CEC—Consolidated Edison Co. of New York, Inc. 4 Irving Place, New York 3, New York.

EW—Electrical World, McGraw-Hill Publishing Co. 330 W. 42nd St., New York 18, N. Y.

GPC—General Petroleum Corp. of California, 2525 East 37th St., Los Angeles 11, Calif.

INCO—The International Nickel Co., Inc. 67 Wall Street, New York 5, New York.

IP—Institute of Petroleum, 26 Portland Place, London W2 1, England.

MA—Metallurgical Abstracts, Institute of Metals,

London, England. 4 Grosvenor Gardens, London SW 1, England.

MR—Metals Review, American Society of Metals, 7301 Euclid Ave., Cleveland 3, Ohio.

NALCO—National Aluminate Corp. 6216 West 66th Place, Chicago 38, Illinois.

NBS—National Bureau of Standards, Supt. of Documents, U. S. Gov't Printing Office, Washington 25, D. C.

PDA—Prevention Deterioration Abstracts, National Research Council, 2101 Constitution Ave., Washington 25, D. C.

RA—Refrigeration Abstracts, American Society of Refrigeration Engineers, 40 West 40th St., New York 18, N. Y.

RM—Revue de Metallurgie, Paris, France, 5 Cite Pigalle, Paris (9e), France.

RPI—Review of Current Literature Relating to the Paint, Colour, Varnish and Allied Industries, Research Association of British Paint, Colour & Varnish Manufacturers, London, Waldegrave Rd., Teddington, Middlesex.

TDD—Technical Data Digest, Air Material Command—Technical Service Section, Central Air Documents Office, Wright-Patterson Air Force Base, Dayton, Ohio.

TIME—Transactions of Institute of Marine Engineers, 85 The Minories, London EC 3, England.

UOP—Universal Oil Products, 310 South Michigan Ave., Chicago, Illinois.

ZDA—Zinc Development Association, Lincoln House, Turl Street, Oxford, England.

niques were used. Typical patterns are illustrated and discussed. Points out application of the method to the fundamental study of corrosion and of secondary-electron emission.—BLR.

1.8, 6.3, 3.5

Kinetics of the Oxidation of Titanium. W. A. Alexander and L. M. Pidgeon. *Can. J. of Res.*, 28, sec. B, 60-82 (1950) Feb.

Rates of oxidation of titanium powder and sintered bars were investigated from 25 to 550°C at pressures of 2 and 20 cm. oxygen. Shows that the oxidation process can be divided into two mechanisms. Develops equations representing each. 43 ref.—BLR.

1.8, 3.6, 3.5

Influence of Interfacial Potential on Friction and Surface Damage. F. P. Bowden and L. Young. *Research*, 3, 235-237 (1950) May.

Presents experimental study of the above as applied to inert metals, such as platinum, immersed in an electrolyte. Shows that small changes in interfacial potential have a profound effect, both on friction and on the surface deformation. Results are explained in terms of the electrodeposition and electrosolution of adsorbed gas layers, and also of electrical interaction of the charged double layer. 12 ref.—BLR.

TESTING

● Laboratory Methods and Tests

2.3

Scattering and Multiple Tests in the Study of Corrosion. (In French.) L. Cavallaro and A. Indelli. *R. de Metallurgie*, 46, 758-761 (1949) Nov.

Discusses the suitability of accelerated laboratory tests, involving scientifically scattered data, for corrosion studies; as contrasted with the more reliable, but time-consuming multiple-test technique. 15 ref.—BLR.

● Instrumentation

2.4

Localization of the Defects by X-Rays. by F. Baldi. *Metallurgia Ital.*, 42, No. 4, 133-135 (1950) April.

The paper describes a method for the localization of the defects in metal parts which is based on taking two radiographs on two separate films. The results are satisfying and the order of precision is more than sufficient for the normal controls.

PREVENTIVE MEASURES

● Non-Metallic Coatings and Paints

5.4

Some Special Applications for Organic Finishes. J. L. Bleiweis. *Org. Fin.*, 10, No. 10, 12-4 (1949); *Chem. Abs.*, 44, No. 2, 852c (1950).

A review is given of special additions for organic finishes. Some examples include special driers for wrinkle finishes,

inorganic materials for anti-corrosive properties in primers, materials to retard barnacle formation, and materials to which DDT has been added. Organic finishes can also be applied to plastics to improve the gloss, or to metallize the surface in preparation for electroplating.—RPI.

5.4, 2.3, 3.5, 1.7

A Study of Heat Resisting Finishes. G. Black. *Prod. Fin.*, 14, No. 5, 38-42 (1950) Feb.

A discussion on the work and findings of the Houston Paint and Varnish Production Club in comparing various heat resistant finishes under conditions resembling those met in service. 50 paints were compared with an aluminum bronze/silicone paint which seemed unaffected after 40 hours heating at 1000°F. Four paints had a comparable life, two of them pigmented with zinc dust/zinc oxide/graphite. In one case the vehicle was a mixture of refined linseed and fish oils bodied together, in the other silicone resin No. 801. The last mentioned paint was the best on atmospheric exposure, but the results suggested that none of the heat resistant paints was really satisfactory out of doors.—ZDA.

5.4

Styrene Copolymers in Alkyd Resins. N. R. Bhow and Henry F. Payne. *Ind. Eng. Chem.*, 42, 700-703 (1950) Apr.

A laboratory process is described for completing both the copolymerization and the alkyd resin reactions in 4-6 hr. Evaluation of experimental styrenated alkyds in clear films and in white enamels showed that they have superior drying time and chemical resistance to conventional phthalic alkyds. 11 ref.—BLR.

5.4, 7.5, 8.4

Synthetic Coatings for Gasoline Tanks. PB. 22812, Frames 4; Board of Trade, Tech. Inf. & Docs. Unit, FD, 193-50.

A description of the coatings applied to the inside of steel tanks used for the storage of petrol, together with details of the application, is included. For the small tanks (up to 250 gallons capacity) a baked phenol/formaldehyde resin was used; for the large tanks, a NC lacquer was substituted.—RPI.

5.4, 3.3

Tall Oil and Rosin Derivatives in Toxic Paint Vehicles. A. L. Alexander, R. L. Benemelis, and S. B. Crecelius. Papers presented at the Atlantic City Meeting of the Div. of Paint, Varnish & Plastics Chem., Am. Chem. Soc., 153-60 (1949); *Ind. Eng. Chem.*, 42, 1562-65 (1950) Aug.

Anti-fouling formations based on tall oil/rosin and on rosin with hydrogenated methyl abietate, abietic acid and the glycerol and pentaerythritol esters of tall oil were examined. The paints were pigmented with either metallic copper or cuprous oxide. Results of exposure trials show that anti-fouling effectiveness is more dependent on the nature of the matrix than on the chemical state of the copper. With formulations in which rosin was diluted with abietic acid, hydrogenated methyl abietate or unesterified tall oil, performance was equal to rosin. Tall oil esters even in low concentrations destroy the anti-fouling properties. 4 refs.—RPI.

5.4

(Vinyl Resin) Coatings for Industry. *Bakelite Rev.*, 21, No. 3, 19-21 (1949). *NPVL Abs.*, 1950, No. 153, 11.

Successful uses of vinyl resins in marine coatings, masonry paint, tank coatings, and pipe coatings are described.—RPI.

5.4, 6.4, 2.3

Vitreous Enamelling of Aluminum and Aluminum Alloys. J. C. Bailey and Marjorie E. Whitaker. *Light Metals*, 12, No. 134, 139-156 (1949).

An account is given of comprehensive tests on the performance of a number of vitreous enamels suitable for use on aluminum and its alloys. The firing temp. must be limited to 550°C, or less in some cases, and B. and W. have examined a number of existing enamels with additions of lead compounds and one leadless glaze which meet this condition. Wrought products have been found to require no more than degreasing or a chromate dip as a pretreatment, but it has been found desirable to etch away the skin of castings in order to obtain good adhesion. The oxide film on a metal plays an important part in promoting good adhesion of a vitreous enamel and, in the case of aluminum and its alloys, the good adhesion of the oxide film facilitates the application of the enamel and promotes excellent adhesion. Tests along the lines of those laid down in B.S. 1344 show that all the enamels possess good resistance to thermal shock, heat and mechanical damage. Chemical durability and resistance to moisture and weathering were not so good. A commercial appraisal is appended (pp. 154, 157-159).—MA.

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• Packaging

5.6, 6.3

Prevention of Corrosion in Storage. C. L. Bulow, Bridgeport Brass Co. *Copper Alloy Bull.* (1950) Apr.

It has been shown that chloride contaminated paper can lead to objectionable corrosion of copper and copper alloys—particularly when a humid atmosphere prevails in storage areas. The inertness of the solvent or impregnating medium for sizing is of utmost importance and should be chloride-free. Paper, even in the absence of corrosion accelerators as sulfur and chlorine, can under humid conditions become corrosive. At humidity above 75 percent the amount of water-vapor absorbed by the paper increases rapidly. Paper and wood may undergo bacterial decomposition with the formation of carbon dioxide, etc., which can lead to the formation of bright green copper carbonate. In very severe cases, this overlay may be a bright red powder or crystalline layer of copper oxide. Paper and wood impregnated with corrosion inhibitors, wax, and other materials offer a solution to this storage problem. Packaging for long storage is accomplished by the use of those water-resistant wrappings having low rates of water-vapor transmission.—INCO.

5.6

The What and How of Glassine. George C. Borden, Jr., and Paul K. Wolper. *Modern Packaging*, 23, 111-117, 169 (1950) Aug.

Describes basic properties and applications of above protective packaging paper. Comparative properties of coated and laminated glassines and allied sheet materials are tabulated.—BLR.

• Surface Treatment

5.9, 6.4, 5.4

Adhesion of Paints. L. Bonnat. *Trav. Paint.*, 4, No. 11 bis (Special No.), 35 (1949).

The effect of pretreating metal surfaces, particularly light metals, on the adhesion of paint films is discussed.—RPI.

5.9, 6.4

Anodic Oxidation Finishes for Aluminum and Aluminum Alloys. British Standards Institution, British Standard 1615:1949, 23 pp. Published by the Institution, 28, Victoria Street, London, S.W.1. 3s.

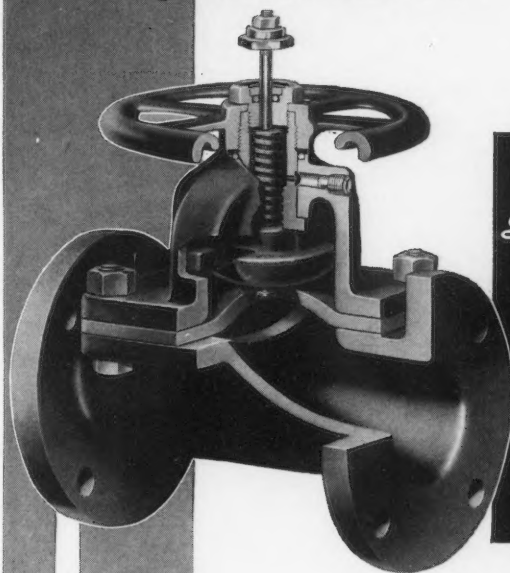
Specifies thickness of anodic coating, reflection factors and surface finish of reflectors, resistance to abrasion and fastness to light. It is not intended to standardize the anodizing process itself; resistance to corrosion is still under consideration. Appendices (pp. 7-23) give approved methods of test and a method for preparing standard coatings.—BNF.

5.9, 8.4

Chemical Cleaning. V. E. Bowes, Oak-ite Products, Inc. *Petro. Eng.*, 22, No. 5, C20-C22 (1950) May.

Cleaning heat exchangers in the refinery consists of circulating chemical cleaning materials through the shell and tube sides, or of immersing the pulled tube bundle in a tank of specialized cleaning solution. The cleaning solutions

Here is the valve that revolutionized flow control of Sulphuric Acid . . .



HILLS-McCANN
Saunders Patent
DIAPHRAGM
VALVE
with L-1
PLASTIC
DIAPHRAGM

Sulphuric acid up to 66° Bé can now be valved without leakage, dripping or sticking . . . with Hills-McCanna Diaphragm Valves equipped with the new L-1 plastic diaphragms. This new development combines the tried and proved Saunders Patent pinch clamp principle with a diaphragm of a special type of plastic that is particularly resistant to concentrated sulphuric acid.

Hills-McCanna Diaphragm Valves with L-1 diaphragms are suitable for temperatures up to 125° F. and pressures up to 100 psi. Sizes from ½" thru 4" are available, handwheel operated, quick opening (lever operated) and sliding stem models. Choice of nearly 50 body materials or linings including cast iron, cast steel, Durimet or glass lined.

Literature is available describing Hills-McCanna Valves with data on their use for acid and other services. Write for your copy outlining the nature of your application. **HILLS-McCANN COMPANY**, 2640 W. Nelson St., Chicago 18, Ill.

The valve illustrated in cut-a-way above is the Hills-McCanna Model 6600 semi-sealed bonnet acid valve with L-1 plastic diaphragm and tell-tale travel stop indicator. Valves of this type can be furnished where particularly rigid safety precautions must be taken.

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and details on cleaning the exchangers in place or with mobile units are described. Diagrams.—INCO.

5.9, 6.3

Cleaning Copper Parts. *Amer. Machinist*, 94, No. 9, 113 (1950) May 1.

The solvent cleaning, degreasing, alkaline scouring, emulsion, scrubbing, electrolytic cleaning, tarnish removing, pickling, and bright dip of copper parts are discussed.—INCO.

5.9, 8.9

Machine for Cleaning Metal Surfaces. Admiralty Corrosion Committee, Hull Corrosion Sub-Committee. ACSIL/ADM/48/427. *J. Brit. Shipbuilding R. A.*, 4, Abstract No. 2527, 156 (1949) Mar.

An American firm has developed a machine for cleaning metal surfaces by a process which can be regarded as a development of sandblasting. Grit is directed through a "gun," on to the surface to be cleaned, and is then sucked back through the gun, together with the scale or paint removed from the surface, into a reclaiming tank. Here the dust is separated from the grit, and it is then passed into a dust collector. An alternative gun is provided for use at right-angled intersections. The machine consists of three units: the gun, the reclaiming tank, and the dust collector. Although the machine will operate at air pressures as low as 60 lb. per sq. in., the rate of cleaning is considerably lower than at 85 lb. per sq. in. The makers claim that up to 75 feet length of hose between the reclaimer and gun can be used. They also claim that the dust collector unit may be as much as 200 feet from the gun. For work on steel plate surfaces, a hard steel grit is recommended, of which 70 percent will pass through a 0.028 inch-mesh screen. For efficient operation, the air supply must be dry, the surface must be reasonably dry, and it must not be raining. The tool would appear to be of most use on superstructures and other exposed steel surfaces of vessels which are to be laid up for a considerable period. Although for new shipbuilding and for ships in commission its general adoption would probably not be justified, it would probably lead to economy if it were used in areas of the upper works and the internal structure where access is difficult and sweating is likely.—TIME.

5.9

Metal Cleaning Problems and Tests for Cleaners. Adolph Bregman. *Metal Prog.*, 57, 339-340+ (1950) Mar.

A previous article briefly discussed the main types of cleaning methods. This article deals more specifically with some of the cleaning methods and surveys numerous tests used for evaluating the effectiveness of cleaners.—BLR.

5.9

Preplating Cleaning Treatment. A. K. Beenie. *Plating Notes* (Defense Research Laboratories, Australia), 2, No. 1, 2-14 (1950) Feb.

Descaling of steel parts (with very brief note on non-ferrous metals); alkaline cleaning; solvent degreasing.—BNF.

5.9, 6.4

Report of Test of "Alodizing" Process for Anodic Treatment of Aluminum Alloys. U. S. Naval Engineering Experimental Station. Am. Chemical Paint Co.

Test C-3201; 1948; *Prev. Det. Abs.*, 7, Met 177 (1949).

Unpainted Aluminum alloy panels were treated with the proprietary "Alodizing" processes and two anodizing treatments in H_2SO_4 and chromic acid. The unpainted anodized specimens had good resistance. The Alodized treatment provided a good paint base.—RPI.

5.9

Treatment of Ferrous Metals for Cold Deformation and Anti-Rust Protection. G. Baretta. *Pittura e Vernici*, 5, No. 12, 525-6 (1949); also in *Ind. della Vernice*, 3, No. 31, 234-6 (1949).

A review of phosphatization processes.—RPI.

5.9

Rust Removal by Chemical Means. H. C. Burmeister. *Farbe u. Lack*, 55, No. 3, 77-81 (1949).

Pickling solutions usually contain inhibitors to limit attack on the metal. The mechanism of their action, and the effect of pickling on surface structure, etc., are discussed.—RPI.

5.9, 8.9

Soft-Grit Blasting: Non-Damaging Process for Cleaning Metal Surfaces. *Aircraft Prod.*, 11, No. 133, 369 (1949).

A brief description is given of a surface-cleaning process in which soft grit manufactured from fruit stones is used instead of sand or shot. Advantages obtained by the use of soft grit include: 1) paint, lacquer, varnish, and rust may be removed without damaging the original surface; 2) the process may be used where considerations of accuracy and surface finish preclude sand or shot blasting; and 3) the process may be safely used on aluminum alloy components.—MA.

5.9

Soft Grits for Blast Cleaning. *American Mach.*, 94, 127 (1950) June 12.

Describes grits prepared from corn cobs, nut shells, and fruit pits used in conventional sandblasting equipment for efficient removal of paint, dirt, grease, carbonaceous deposits and scale without impairing the surface or dimensions of metal workpieces.—BLR.

5.9, 5.8

Tumbling for Low-Cost Finishing. Adolph Bregman. *Metal Prog.*, 57, 625-628+ (1950) May.

Describes general principles, procedures and equipment. Discusses characteristics of the carrier or rolling medium, and of the finishing compounds (abrasives, lubricants, cleaners and corrosion inhibitors). Also discusses dry tumbling. Recommends wider application of tumbling.—BLR.

5.9, 5.4

Wash Primer. *Bakelite Rev.*, 21, No. 1, 22-23 (1949); *NPVL Abs.*, 1949, No. 149, 192.

A phosphoric acid/Zn chrome/vinyl butyral wash primer has been successfully used on a diversity of metal surfaces, particularly the marine type. The primer has been successful in increasing the service life of the paint system and increasing production efficiency. It has also prevented creepage of corrosion under the edges of paint film when exposed by abrasion.—RPI.

MATERIALS OF CONSTRUCTION

• Ferrous Metals and Alloys

6.2, 1.7

Data on Corrosion- and Heat-Resistant Steels and Alloys, Wrought and Cast. American Society for Testing Materials. Brochure, 1950, 79 pp. Published by the ASTM, 1916 Race St., Philadelphia 3, Pa., U.S.A. \$2.50 (\$1.85 to ASTM members).

Part I of this booklet, which covers wrought chrome and chromium-nickel steels, is a revised version of "Tables of Data of Chemical Compositions, Physical and Mechanical Properties of Wrought Corrosion-Resisting and Heat-Resisting Chromium and Chromium-Nickel Steels," issued by the ASTM in 1942; it now includes available data on new steels. Part II (pp 65-79) similarly covers the properties of cast chromium-, chromium-nickel and nickel-chromium steels.—BNF.

6.2

High Strength Steels. C. L. Altenburger. *AISI, "Technical Committee Activities,"* 278-292 (1949).

Corrosion resistance, welding, forming, drawing, mechanical properties, and design possibilities.—MR.

6.2, 5.3, 5.4

Protective Coatings for Iron and Steel. British Cast Iron Research Association. *Bull. Brit. Cast Iron R.A.*, 10, No. 5, 194-200 (1950) Mar.

Brief notes on a large number of processes for providing protective coatings on iron and steel including enameling. Includes many proprietary processes. Bibliography of 37 references.—BNF.

• Non-Ferrous Metals and Alloys—Heavy

6.3, 1.6, 1.7

ASTM Standards on Copper and Copper Alloys. ASTM. 9 x 6 in. Pp xi +496 (1949). Philadelphia 3, Pa. The Society, 1916 Race Street. (Heavy paper cover \$4.35; cloth cover, \$5.)—MA.

6.3, 3.5

New Cobalt-Base Alloy for High-Temperature Sheet. W. O. Binder and H. R. Spendlow, Jr., *Metal Prog.*, 57, 321-326 (1950) Mar.

Describes superior high-alloy sheet, for use at temperatures up to 1800°F, based on cobalt (50%), chromium, nickel and wolfram. While strong and stiff, it can be readily formed in bending, stamping and drawing; has good weldability and high resistance to oxidation. Optimum properties are developed by brief heating at 2200°F, followed by air cooling.—BLR.

6.3, 6.4, 1.6

The Non-Ferrous Metal Industry in Germany During the Period 1939-1945. By Leslie Aitchison and Voya Kondic. BIOS Surveys Report No. 23. Med. 8vo. (1949) 198. London: H.M. Stationery Office. (3s. 6d. net.)

This survey provides a convenient and

highly condensed version of the vast amount of scientific, technical and industrial information on the production and use of non-ferrous metals, which was obtained by the teams of experts visiting Germany immediately after the war. It is divided into four main parts dealing, respectively, with light, base, rare and precious metals, a total of twenty-nine metals being mentioned in 57 pages of text and 129 pages of references and bibliographies of relevant official reports and FD and HEC documents. The information is presented in proper perspective, and it is apparent that although many of the methods described were only successful as a result of German war-time economic conditions, many others are capable of being, and probably will be, further developed and become of commercial importance. Wherever possible, production rates and costs are given, thus enabling direct comparisons to be made with normal British practice. The two authors are to be congratulated on having produced such a comprehensive, authoritative and readable summary of recorded German experience, which is of great use to all engaged in the non-ferrous metal industry.—MA.

6.3, 3.5, 4.7, 3.7

Preparation and Properties of Titanium-Base Alloys. P. H. Brace, W. J. Hurford and T. H. Gray. *Ind. and Eng. Chem.*, 42, No. 2, 227-236 (1950).

Read before the Division of Industrial and Engineering Chemistry of the American Chemical Society. The chief results of an investigation of the preparation and the mechanical properties of a number of titanium-base alloys with particular reference to their behavior in cast form at high temp., are given. The alloys were prepared by melting and casting in vacuum or under an atmosphere of highly purified argon in a specially constructed furnace system which, by rotation about a horizontal axis, transferred the metal from the inductively heated melting chamber to a mold that was preheated by means of an electrical resistance unit. Extensive tests were made on the suitability of the refractory materials; thorium oxide proved to be the most satisfactory and the only one which could be used under the conditions employed. Molten titanium was found to react exothermally with aluminum oxide and to a lesser extent with beryllium oxide, the resultant product being quite different from the titanium used in the test blocks. A slight but perceptible reaction was also found with thorium oxide, but the latter proved satisfactory as a crucible material. Graphite was not satisfactory for crucibles but both it and a soft-bodied magnesite could be used as a mold. Quantitative tensile data for as-cast specimens are given for tests by const. strain rate and creep-rupture methods at several elevated temp., together with information concerning oxidation characteristics. Alloys containing more than 95 percent titanium exhibited surprisingly good resistance to oxidation in air up to $\sim 900^\circ\text{C}$. Among the more highly alloyed compositions the stronger showed yield strengths at 950°C comparable with those of such high-temp. alloys at No. 31 Stellite, and in some cases the ratios of yield strength:weight were favorable. Many of the stronger alloys, however, were brittle at room temp., and the results suggested that the use of wolfram and molybdenum

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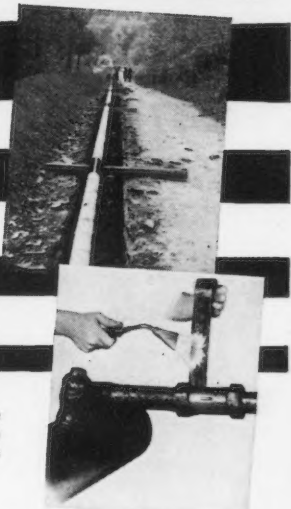
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together gives more favorable properties than are obtained when either metal is used alone. Oxygen is not a particularly desirable alloying element.—MA.

6.4, 4.6, 3.7

The Action of Boiling Distilled Water on Aluminum. J. M. Bryan. *J. Soc. Chem. Ind.*, 69, 169-173 (1950) June.

Aluminum and Aluminum alloys react initially with boiling water with the evolution of hydrogen, but the action is quickly arrested through the formation of a highly resistant film of alumina monohydrate. Impurities and alloying elements in the metal and emery treatment of the surface have some influence on the reaction, but the most important factor appears to be the presence of a certain minimum quantity of silicon in the metal. 20 references.—INCO.

6.4, 4.3

Cast Aluminum Bronzes. (In Italian.) Istituto Sperimentale dei Metalli Leggeri. *Alluminio*, 18, No. 6, 635-657 (1949) Nov.-Dec. (Note d'Officina No. 18.)

Structure, casting technique, heat treatment, corrosion-resistance to several chemicals, mechanical and physical properties of various bronzes. Several micrographs.—BNF.

6.4, 2.2, 3.7

Corrosion Behavior of Aluminum Alloys. Admiralty Corrosion Committee, Hull and Non-Ferrous Corrosion Subcommittee, ACSIL/ADM/48/900. *J. of the Brit. Shipbuilding R.A.* (England), 5, Abstract No. 3595 (1950) Apr. *Trans. Inst. Mar. Eng.* (England), 62, No. 6, 84 (1950) June.

This report, illustrated by photographs, gives the results of exposure tests of eighteen weeks and indicates that there is little to choose from a corrosion resistance standpoint between any of the four aluminum alloys under tests. The 3 percent magnesium alloy (AW5C) appears to be the most resistant to corrosion, with the 5 percent magnesium (AW6D) almost as good. Both the 1½ percent magnesium and clad dural are slightly inferior to these two, although the relative performances of all four materials under all conditions of test are very close. Joined to themselves, or joined with aluminum rivets to galvanized steel, painted or unpainted, all the alloys possess good corrosion resistance but coupled to more cathodic materials, the progress of corrosion is rapid. With a higher quality protective paint, however, it is conceivable that performance under these conditions might be improved. Unless the whole of the exposed aluminum surface, including rivet heads and points, can be given identical treatment, surface pre-treatment appears to be undesirable. When areas such as rivet heads are left untreated, attack in these areas is very much more rapid. In the tested materials, corrosion of rivet points when in contact with more cathodic materials is very much more rapid than on the rivet heads, and it is proposed to conduct electrode potential measurements to try to establish the relative tendency to corrosion of work-hardened as opposed to annealed rivet materials. It is emphasized that the results of these visual assessments can only be applied with caution; also that the fact that the area of aluminum to dissimilar metals in each specimen is electrochemically significant and would have a great deal of effect on the corrosion behavior of the metals in contact.—ALL.

6.4, 3.5, 3.7, 3.2

Corrosion of Aluminum Alloys (La corrosione nelle leghe leggere). P. Brenner. *Alluminio* (Italy), 19, No. 3, 225-236 (1950).

A review of the corrosion phenomena of aluminum alloys is given, describing in detail the main types of attack, giving micrographic illustrations for each of them. The following corrosion phenomena are described: even corrosion, pitting corrosion, intergranular corrosion, corrosion not plainly drawn, corrosion on castings, on clad material, on machining cuts, and on welded joints. It is suggested that a corrosion chart for light metals and other metallic materials be compiled.—ALL.

6.4, 4.4, 2.3

The Corrosion of Aluminum and Aluminum Alloys by Citric Acid and Citric Acid/Salt Solutions. J. M. Bryan. *J. Science of Food & Agriculture*, 1, No. 3, 84-87 (1950) Mar.

Aluminum Al-1.2 Mn and Al-1.8 Mg-0.5 Mn alloys were tested in citric acid and in citric acid/NaCl solutions. All materials resisted citric acid at room temperature but the rate of attack was too high to permit use in citric acid at high temperatures or in citric acid/NaCl at any temperature. In general, the purer the Aluminum the less was the corrosion.—BNF.

6.4, 3.2, 3.5

Forms of Appearance of Corrosion in Aluminum Alloys. P. Brenner. *Metalloberfläche* (Germany) Ausgabe A, 4, No. 1, Al-Al3 (1950) Jan.

An illustrated account of the various forms of corrosion is given, including: uniform superficial corrosion; pitting; intercrystalline and transcrystalline corrosion; mixed corrosive attack; special cases (layer corrosion, stress-corrosion cracks along the lines of primary crystals in extruded bars, corrosion without sharp delimitation, corrosion in the cast state); corrosion of clad materials, of cut edges and of welds. Numerous micrographs are shown and 18 references are given.—BNF.

6.4, 5.9, 5.4

Protective Coatings on Magnesium. A. W. Bohnisch. *Lack-u.-Farben-Chem.*, 3, No. 5/6, 86-9 (1949).

The occurrence, properties and uses of magnesium are outlined. The method of electrolytic oxidation is described and the various pickling baths used are surveyed in some detail. Suitable coating compositions are described.—RPI.

• Metals General or Multiple

6.5, 2.5, 5.3, 1.6, 1.7

1949 Book of ASTM Standards Including Tentatives, Part II—Non-Ferrous Metals. Published by the American Society for Testing Materials, Philadelphia (U.S.A.) 1140 pages, 1950.

This latest edition of ASTM Standards groups together in separate sections the standards and tentatives in a particular materials field preceded by an appropriate title page. Materials subdivisions are as follows: Copper and copper alloys; Aluminum and magnesium and their alloys; Die-cast metals and alloys; Metal powders and metal powder products; Electrical heating, resistance, and

related alloys; Electrodeposited metallic coatings; Corrosion tests; Non-ferrous metals and alloys and General methods of testing. There are thirty specifications for aluminum and aluminum alloy products and six for magnesium.—ALL.

• Non-Metallic

6.6

Molded Ceramics. R. W. Bolz. *Machinist Design*, 22, No. 8, 145-153 (1950) Aug.

An outline of the requisites and methods in ceramic manufacture by the plastic wet and dry process. Extrusion, throwing, jiggering, pressing, casting, vacuum extrusion and pressing are discussed. Wall thickness, fillets and radar, ribs, draft, grooves, holes, threads, machining, firing surface and lettering in regard to design considerations are explained. Ceramic materials are chosen for industrial equipment because of corrosion, heat or wear resistance. Illustrations and table of ceramic properties.—INCO.

6.6, 3.3

Recent Developments in Wood Impregnation with Fluorine Compounds. (Neue Erkenntnisse ueber Fluor-Verbindungen in Holzschutz). G. Becker. *Angewandte Chemie*, 62, No. 16, 382-385 (1950) Aug.

The suitability of fluorides and fluoro-silicates as wood impregnators is chiefly due to their fungicidal and insecticidal actions which surpass those of most inorganic impregnators known thus far, except certain mercury, thallium and arsenic compounds. Penetration tests with various fluorine compounds show the hydrogen fluorides to exceed the penetrating power of all other compounds, because of the high diffusivity of free gaseous hydrogen fluoride. The toxicity of this compound, however, restricts its applicability to special purposes. A drawback in the use of fluoro-silicates lies in their high corrosive action on metals, notably on iron. Until a means can be found to prevent this action, the neutral and weak alkaline fluorides must replace the more effective silicates and hydrogen compounds wherever the problems of metallic corrosion might arise.—TDD.

6.6

Service Tests on Posts as a Means of Evaluating Wood Preservatives and Methods of Treatment. J. O. Blew. U. S. Forest Service, Forest Products Lab., 1948, No. D1726, 15 pp. *Prev. Det. Abs.*, 7, W 46 (1949).

Important factors in service tests on treated posts include the selection of posts and preservatives, the method of application, installation, inspection and the reporting of results. Each of these factors is discussed in detail.—RPI.

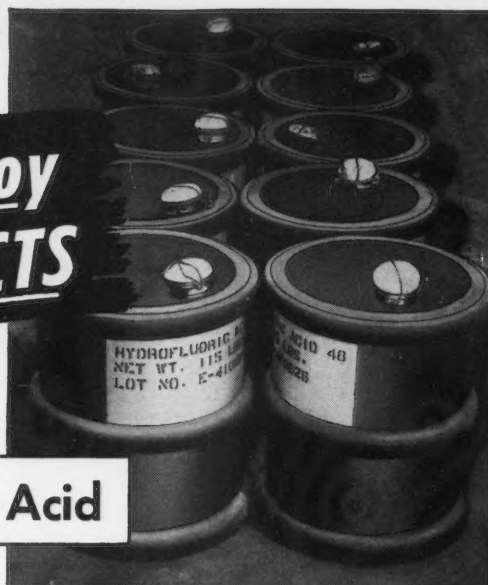
6.6

Some Experimental Observations on the Photochemical Degradation of Dyed Cotton. D. Ashton, D. Clibbens & M. E. Probert. *Soc. Dyers & Col. Symposium on Photochemistry in Relation to Textiles*, 51-8 (1949)

Certain dyes sensitize the photochemical oxidation of cotton in air. Small amounts of copper diminish the sensitizing action. Many dyes liberate hydrogen

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peroxide on irradiation in moist air, but this action is prevented by the presence of small amounts of copper and other metals. There is a correlation between the sensitizing action and hydrogen peroxide production.—RPI.

6.6, 3.3

Tests of Treated Fence Posts Against Termites. J. Beesley & R. W. Bond, Austral. Council for Scientific and Industrial Research, Div. Forest Products; Sub-project P. 4-2. Progress Rept. No. 4, Austral. Scientific Liaison Office, Washington; Austral. Tech. Paper No. 1784 (1949). *Prev. Det. Abs.*, 7, W 71 (1950).

Tests posts of red stringy bark and apple box were treated either with a 7:3 mixture of creosote and crude oil, or with an aqueous solution of 3.5 percent zinc chloride containing 2 percent arsenic. Both treatments were effective, the posts being generally in good condition after 13½ years' service.—RPI.

6.6, 3.3

Toxicity of (Wood) Preservative Oils Before and After Artificial Ageing. R. H. Baechler, Amer. Wood Preservers' Assoc. 6 pp (1949) April 26-28. *Prev. Det. Abs.*, 7, W 66 (1949).

Ageing of preservative oils by evaporation was simulated by bubbling air through the hot oils for 7½ hr. A decrease in toxicity of the oil was obtained but no consistent relation between amount of oil lost by aeration and decrease in toxicity was found. An attempt made to accelerate leaching by a washing technique was not successful except with creosotes, when the toxicity diminished.—RPI.

EQUIPMENT

• Engines & Turbines

7.1, 4.3, 5.8

Corrosive Attack. C. B. Boon. *Oil Eng.*, 28, No. 207, 97 (1950) July.

Tests on a gasoline engine with the cylinder temperature at 50° and 100°C indicated that excessive cylinder wear is caused by the corrosive condensation products of combustion. Polar-type lube oil additives such as high molecular weight fatty acids have effective anti-corrosive properties.

7.1, 3.5

Experimental Running of Open- and Closed-Cycle Gas Turbines. J. B. Bucher. *Trans. Instn. Engineers and Shipbuilders in Scotland*, 1950, 275-310; disc. 310-320.

Extremely detailed account of work carried out by John Brown and Company, on the two types of turbines, using gas oil and Britoleum. Blade materials tested were R. ex 337 A, G. 18B, Staybrite FCB, cold-worked FCB, Nimonic 80, and Nimonic 80 A. Examination of deposits in turbine showed nickel oxide 13.7, chrome oxide 18.6, iron oxide 48.4, silica 2.4, sulfate 3.4, vanadium pentoxide 8.3% and traces of lime and magnesia. The rotor blades, except those made from materials having high nickel content, showed distinct signs of sealing, and all blades, with exception of those having high nickel content, had been attacked by the vanadium pentoxide. Conclusion is drawn that considerable difficulties will be experienced in running

open-cycle gas turbines on anything other than distillates, unless a method of cleaning blading without shut-down can be developed. In the discussion T. F. Eden deals in some detail with vanadium pentoxide attack and indicates that in corrosion troubles will be experienced only if the metal temperature is above the melting point of the ash (given as 690°C). In reply, the author (p. 319) refers to further running of the closed-cycle unit on Britoleum.—INCO.

7.1, 3.5

More News of John Brown Tests. J. B. Bucher. *Oil Engine and Gas Turbine*, 18, 13 (1950) May.

Supplementary data of further test work on John Brown's small closed-cycle plant. Continuous run of 120-hr. was completed on special 200-sec. oil with ash content of 0.04%, of which more than 80% was vanadium pentoxide. Special high-vanadium-in-ash oil was tested. Carbon tetrachloride was injected in hope that vanadium chlorides would be formed and be gaseous at 200°C and above, but air heater was found much corroded. Upon examination of scale, it was found that carbon tetrachloride injection increased corrosion. Further data on metal temperatures are given.—INCO.

• Heat Exchangers

7.4, 6.4

Industry Widens Uses of Aluminum Tubing. J. Anthony. *Iron Age*, 165, No. 10, 103 (1950) March 9.

The heat exchanger market has consumed 250,000 pounds of aluminum in the form of tubing during the post-war years, as compared with a prewar total of 10,000 pounds total consumption of the market. Typical installations include vapor recovery condensers, lube oil coolers, hydrogen sulfide gas coolers, furfural condensers, MEA solution coolers and exchangers, and MEK service. The sub-zero physical and mechanical properties of aluminum are very good; strength and ductility improve at low temperatures. Aluminum alloy 61S has a tensile strength of 45,000 psi and an elongation of 17 percent at room temperature; at -320°F (-196°C) the tensile strength is 60,000 psi and ductility 22 percent. Certain chemical and petroleum industry installations including plants for the synthesis of gasoline from natural gas and petrochemical plants use aluminum heat exchangers. Production of Alclad aluminum in the form of tubing which is protected from electrolytic corrosion and is cold-drawn from extruded blooms has expanded the market. A new type of hollow extruded tubing with longitudinal fins on the external and internal surfaces has been developed and facilitates heat transfer by the greater inner and outer exposed surfaces. Several manufacturers will provide a complete line of standard and large size fittings such as flanges, tees, caps, stub ends, reducers, manways, ells, etc. Electronic tube expanding equipment has been developed which will produce uniformly strong and tight joints between tubing and tube sheets quickly and economically. The equipment is set to a predetermined stress, at which point it shuts off automatically. Large exchanger installations made of heavy 1½-in. thick aluminum plate can be welded automatically in two passes using an argon gas shielded arc.—ALL.

7.4, 5.9

Papers on Fouling and Cleaning of Heat Exchange Equipment, Condensers, Etc. American Society of Mechanical Engineers. *Trans. A.S.M.E.* 71, No. 7, 825-883 (1949) Oct.

A series of eight papers including: "The Mechanical Cleaning of Fouled Heat-Exchanger Tubes," by A. John (pp 825-829); "Chemical Cleaning of Heat-Exchanger Equipment," by C. M. Loucks and C. H. Groom (pp 831-836); "Scale Formation and Control in Compression Distillation of Sea Water," by J. J. Campobasso and A. Latham, Jr. (pp 837-838); "Cleaning Tubular Heat Exchangers," by P. F. Dougherty and C. H. Brooks (pp 839-841); "Fouling Rates and Cleaning Methods in Refiner Heat Exchangers," by R. C. Butler and W. N. McCurdy Jr. (pp 843-847); "Rates of Fouling and Cleaning of Unfired Heat Exchanger Equipment," by J. H. Weiland, Jr., R. C. McCay and J. E. Barnes (pp 849-853); "Fouling of Marine-Type Heat Exchangers," by H. E. Bethon (pp 855-869); "The Fouling and Cleaning of Surfaces in Unfired Heat Exchangers: Panel Discussion," by O. P. Bergelin (pp 871-883).—BNF.

• Containers

7.5, 4.3, 6.4

Investigation of the Corrosive Attack of Aluminum Alloy Pressure Vessels Containing Carbon Dioxide. (In German.) P. Schlapfer, H. Gaumann and A. Bukowiecki. *Schweiz. Arch. angew. Wiss. Techn.*, 15, No. 10, 316-324 (1949).

The physical-chemical properties of carbon dioxide and existing information on the corrosion of aluminum alloy pressure vessels containing carbon dioxide are reviewed. The results are described of an experimental study of the corrosion occurring in cylinders containing liquid or gaseous carbon dioxide; cylinders made in a) Avional and b) Anticorodal, were investigated. It is shown that neither gaseous nor liquid carbon dioxide causes corrosion even when saturated with moisture; corrosion occurs only when water is present as a free phase. The attack is not self-stifling, since the corrosion product, aluminum hydroxide, is soluble in water containing dissolved carbon dioxide, the solubility increasing with the pressure of carbon dioxide; when the pressure falls owing to release of the gas, aluminum hydroxide is precipitated in the water phase and forms the typical white efflorescence on the walls of the cylinder. No protection against the attack is afforded by anodizing, since the anodic film is also dissolved by water containing carbon dioxide. In the absence of high concentrations of chloride ions in the water, the rate of attack is so low that it does not constitute a danger. 20 references are appended.—MA.

7.5, 6.4, 4.3, 4.4

Aluminum Alloys for the Storage and Transportation of Chemicals. E. D. Verink, Jr. *Corrosion*, News Section, 6, No. 1, 1 (1950) Jan.

Aluminum alloys are used for items ranging in size from shipping drums for the transportation of many chemicals such as nitric acid and hydrogen peroxide to large storage tanks for formaldehyde having a storage capacity of over 311,000 gallons. The various applications of aluminum in this field are described with several illustrations.—ALL.



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7.5, 8.3, 6.4

Aluminum Containers for Foods. J. M. Bryan. *Food Manuf.*, 25, No. 2, 64-66 (1950).

Because of the abundance and accessibility of supplies of aluminum there is great interest in the substitution of aluminum food containers for tinplate. Aluminum containers are now widely used, particularly in the Scandinavian countries, and B. discusses the advantages and disadvantages of aluminum in food packaging, under such headings as mechanical properties, prevention of can distortion, can fabrication, corrosion.—MA.

7.5, 6.2, 4.3

Stainless Steel Acid Tank. *Amer. Dye-stuff Rep.*, 39, No. 7, 234, (1950), Apr. 3.

A new SMO stainless steel acid tank is used in cloth carbonizing ranges. It has maximum resistance to acid and a longer life than other types, is easier to clean, and has no rubber lining to damage or replace. The tank is constructed entirely of SMO stainless steel so that the need of recovering carrier and immersion rolls is eliminated. Heavy stainless steel channels reinforce the tub on the outside. Mfg. by Riggs & Lombard Inc.—INCO.

• Structural Shapes

7.6

Protective Coating Prevents Slag on Boiler Heating Surfaces. E. F. Walsh, Narragansett Electric Co. *Power Gen.*, 53, 7, 74-75 (1949) July.

Gas surfaces of 430,000-lb. per hr., 1215-psig, 920° F boiler were thoroughly cleaned and coated with lime slurry. After years operation there were no appreciable deposits and no slag difficulties. After similar treatment, new boilers proved to be immune for several months. Cumulatively slag forms, as H_2SO_4 , manufactured from SO_2 , causes ash in flue gas to stick to surfaces. Action of iron oxide catalyst causing conversion of SO_2 to SO_3 can be lessened with the lime slurry, which reduces exposed surfaces.—INCO.

• Electrical and Telephone

7.7, 6.4

From a Metallurgist's Notebook—Aluminum Corrosion. H. H. Symonds. *Metal Ind.*, 76, No. 10, 189-190 (1950) Mar. 10.

Ordinary wall plaster has some slight tendency to corrode switch cases of Cu-Sn-Al alloys containing 0.53 Ni and 0.63 Zn. The choice of the right composition and surface treatment will eliminate this tendency. The switch case should be electrically insulated, so that no galvanic effect will increase the possibility of corrosion. Anodic treatment on the right alloy will virtually eliminate the possibility of corrosion.—INCO.

7.7

Effects of Corrosion of Aluminum Electric Cables: Results of French Investigation. *Wire Ind.* (England), 16, 823-824 (1949) Oct.

Results of inspections of war-damaged aluminum-steel power cables are presented. These cables were made by winding aluminum wires around a galvanized steel core.—ALL.

• Miscellaneous

7.10

Corrosion Resistance of Analytical Weights. P. H. Bigg and F. H. Burch. *Nature*, 165, 201 (1950) Feb. 4.

Service tests of weights made of various materials, in a laboratory atmosphere, indicate that highly polished 25/20 Cr/Ni stainless steel was the most resistant; there was little to choose between less highly polished 25/20 Cr/Ni stainless steel, 80/20 Ni/Cr, and plated weights having a nominal thickness of plating (Pt, Rh or Cr) of about 0.015 mm. or more. Weights coated with a flash of Pt or Rh were not much superior to weights of plain polished brass. A more detailed account of this work will appear later.—BNF.

7.10, 1.7, 4.6

The Deterioration of Steel Sheet Piling Groins at Palm Beach, Florida. C. W. Ross, Army Dept. Summary of Experimental Steel Pile Groins, Palm Beach, Florida, Tech. Memorandum No. 10, published by Beach Erosion Board, Office of Chief Engr., Dept. of Army. Paper before NACE, Ann. Conf., Cincinnati, Apr. 11-14, 1949. *Corrosion*, 5, No. 10, 339-342 (1949) Oct.

Five groins were built and carefully observed in a cooperative study by the Beach Erosion Board and five steel manufacturing companies in order to determine the factors affecting the life of steel groins at this location. The sand profiles of the groins were determined at 39 inspections and the thickness of the piles at selected points was measured three times during the years 1937-1946. Holes appeared in piles of 0.373 in. steel in about four years. The chief factor in the deterioration of the groins was the abrasion by the sand moved back and forth by the waves which removes the protective coating of rust, allowing rapid corrosion, and perhaps also abrades the steel.—INCO.

7.10, 6.4, 2.3

The Aluminum Nail. *Arch. Forum*, 92, No. 4, 189-190, (1950) Apr.

Aluminum nails compete with other nonferrous metals on both performance and cost for certain applications such as wood siding, cedar shakes and shingles, asbestos siding and shingle, wood roofing, gypsum lath, insulated siding, and aluminum roofing. For use with aluminum roofs, several manufacturers produce a special screw-cut roofing nail with a neoprene washer under the head. The screwcut nail demands a slightly bigger bore in the roofing, but the washer is expanded by the jolt of the hammer when the nail head is over the bore, and plugs it effectively. Tests have been conducted which prove the superiority of aluminum nails in their resistance to corrosion and staining in industrial or marine atmospheres. The light weight is advantageous for carpenters since an apron full of aluminum nails is about a third as heavy as steel nails. Accelerated tests have also been conducted with aluminum nails in asbestos cement siding and the corrosion resistance has been good. The nails are resistant to any alkali which is leached from the siding because of a protective film which the metal develops. The same tests showed that neither lime-base plaster nor gypsum-base plaster had any harmful effects on the aluminum alloys tested.—ALL.

INDUSTRIES

• Group II

8.2, 5.3

Field Experience with Corrosion Protection of Galvanized Steel Substation Structures. S. L. Miller, Union Elec. Co. of Mo. Paper before NACE, Fifth Ann. Conf., Cincinnati, April 11-14, 1949. *Corrosion*, 6, No. 4, 120-122, (1950) April.

Excellent corrosion protection is afforded to steel substation structures for several years with one-coat application of lead sub-oxide and aluminum, Type A, paint, if applied before galvanizing is completely deteriorated. Other types of corrosion protectors have poor adhesion to weathered galvanizing, lack of adequate pigmentation, failure by cracking, chipping or blistering, and difficulty in maintaining pigment suspension.—INCO.

8.2

Climatisation of Radio Equipment. *Radio Tech. Dig., Edn. franc.*, 3, No. 2, 115-20 (1949); *Wireless Eng.*, 26, No. 310, A.136 (1949); *Bull. Brit. Sci. Instr. R. A.*, 4, No. 11, 340 (1949).

A note is given reviewing modern methods of protection against extremes of temperature, humidity, fungi and insects. 70 refs.—RPI.

• Group III

8.3, 6.4

Results of Danish Experiments on Packing of Food in Aluminum Cans. (In French.) Bramsnaes. *Revue de l'Aluminium*, 26, 404-407 (1949) Dec. Condensed from *Revue Belge des Fermentations et des Industries Alimentaires*.

Based on systematic tests carried out by the research laboratory of the Danish Ministry of Fisheries. It appears that, generally speaking, aluminum is as good as tin plate and sometimes even better. Products take no metallic taste and do not blacken. The longest periods of preservation were obtained with anodized aluminum cans; or better, anodized and varnished cans.—BLR.

8.3

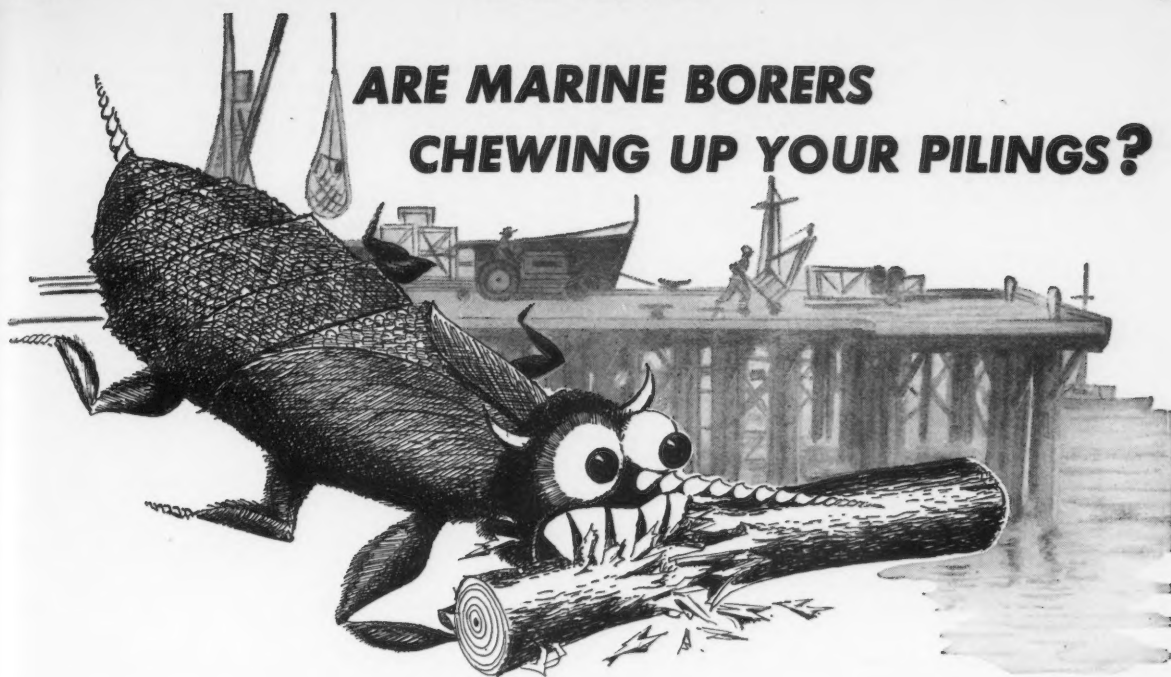
Metals in the Preparation of Wines. H. E. Searle, F. L. LaQue & R. H. Dohrow, International Nickel Co. *Journ. Vinicole*, 1948, No. 6439, Dec. *Chem. Abs.*, 43, 7188 (1949).

Corrosion of apparatus, after each step in preparation of wine from grape juice, was determined for apparatus made from Inconel, stainless steel, Ni, Cu, Monel, Al, and pewter. Least corrosion and subsequent effect on desirable properties of wine were noted when stainless steel and Inconel were used.—INCO.

8.3, 6.3

Zirconium in the Operating Room. J. I. Bates. *Montreal Neurological Inst. Foote Prints*, 22, No. 1, 5-9 (1950).

For bone grafts tantalum plates and plastic plates are most commonly used. Vitallium is used to repair bile duct injuries, and 18-8 SMO stainless steel is used to sew up wounds and to plate fractures. The metals used as structural replacements are subject to stress corrosion, and only tantalum was formerly used with safety in cranioplasty, as



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small hemostatic brain clips, and as thin sheets around cut nerves. Tantalum is however, difficult to form to required skull shapes. Zirconium can be drawn and shaped easily, is inert below 200°C, has a low specific gravity and is corrosion resistant. There is no body reaction to Zirconium and electrolytic activity in body fluids is minimal. Zirconium can be used in place of tantalum as bone plates, screws, clips, and sutures. Zirconium powder is also being used to mark the location of various operations as frontal lobotomies. 18-8-SMo stainless steel, tantalum, zirconium and vitallium can be buried in human tissue for years without undue irritation. 6 References.—INCO.

8.3

Experiences on the Use of Untinned Cans for Preserving Fruit and Vegetables. H. Serger. *Arch. Metallkunde*, 2, No. 9, 320-322 (1948).

Results show that lacquered untinned cans are only suitable for preserving vegetables such as peas, carrots, broad beans, &c.; they are not suitable for preserving fruit or anything of an acidic nature.—MA.

8.3

The Amelioration of Corrosion in the Brewing Industry. Hans Steidle. *Brauwelt*, 8, 282-284 (1949).
A review.—MA.

8.3, 5.3

From a Metallurgist's Notebook—Corrosion of Chromium. H. H. Symonds. *Metal Ind.*, 76, No. 9, 167-168 (1950) Mar. 3.

Preservatives or brine added to meat passing through a food processing machine were considered as a possible cause of the failure of the Cr plate on Al-bronze sleeves incorporated in the machines. Examination of the components submitted points emphatically to corrosion of the Cr as being the main cause of trouble. Some evidence exists that the condition of the deposit in respect of cracks and local lack of adhesion, is a contributory cause.—INCO.

8.3, 5.3

Danger of the Use of Galvanized Iron for Storing of Milk. Louis Truffert. *Ann. Falsif.*, 42, 151-161 (1949). *Chem. Abs.*, 44, 240 (1950).

Samples of milk kept in containers of galvanized iron contained 55 and 154 mg. zinc per litre, as compared with 8 and 14 in the controls. The method for determining the zinc content is detailed.—MA.

8.3

Recent Developments in Brewery Plant and Equipment in Scandinavia and U. S. A. J. L. McCowen. Paper before Chem. Eng. Group, Feb. 17, 1948. *Soc. Chem. Ind.*, 30, 10-17 (1948).

Equipment in the brewing industry is almost universally made of stainless steel with the exception of aluminum which is used in Norway. Stainless steel, however, has proved most effective.—INCO.

8.3, 3.6, 3.4

Corrosion in Fermentation and Storage Vessels Handling Beer. H. Netz. *Werkstoffe u. Korrosion*, 1, 249-250 (1950) June-July.

Chemical and electrochemical corrosion in brewery equipment discussed.

Reasons and instances are given. Behavior of protective coatings is discussed.—INCO.

8.3, 5.4

Bactericidal Paints for the Food Industry. H. Rabate. *Trav. Peint.*, 4, No. 5, 208-9 (1949).

Paints for food factories are discussed.—RPI.

8.3, 6.4

The Alcohols and Ethers Contained in the Carbon Dioxide Evolved During the Fermentation of Grapes Are No Longer Lost. *Revue de L'Aluminium* (France), 27, No. 165, 152-153 (1950) April.

By condensing at low temperature the carbon dioxide evolved by the fermentation of grape juice during the making of wine, it is possible to recover important quantities of alcohol and the ethers which give the aroma. Extensive use is made of 99 percent purity aluminum in the alcohol recovery plant which consists of a refrigerator, heat exchanger and baffle separator. The use of aluminum has made it possible to obtain large heat exchanger and condenser surfaces while maintaining a high standard of corrosion resistance.—ALL.

8.3, 5.3

Corrosion Resistant Tinplate, a Product of Laboratory Design. *Can. Metals*, 13, No. 3, 38-39 (1950) April.

The corrosion resistance of tinplate has been improved by the use of cold reduced steel strip. The shelf-life of canned foods can be estimated by the hydrogen evolution test of the plate before manufacture into cans.—INCO.

• Group IV

8.4, 5.8

Influence of Oil in Subsurface Corrosion of Oil-Well Equipment. W. F. Rogers, Gulf Oil Corp. Paper before Gulf Oil Corp., Production Eng. Conf., Pittsburgh, 1949. *Oil & Gas J.*, 48, No. 32, 73-75, 79 (1949) Dec. 15.

A study was made of the effect of the produced oil on subsurface corrosion of oil-well equipment, and the ability of oils to wet steel in the presence of the produced water. The tests included the effect of varying the wetting ability of an oil on its protective effect at different oil-water ratios, and the presence of an initial oil or water film. A method was developed for surveying tubing to determine the presence of oil films in place for the purpose of correlating the oil drop-size ratio, surface oil films, and corrosion history. Wetting agents are now being used commercially to develop surface oil films on steel and reduce corrosion rates. This is resulting in a decrease in corrosion costs for the wells treated and offers the possibility of a practical wide-spread method for treating both sulfide and nonsulfide wells.—INCO.

8.4

The Theory of Corrosion (Corrosion in the Petroleum Industry). A. H. Saurat. *Tech. et Appl. Petrole.*, 4, 754-756, + (1949). *Chem. Abs.*, 43, 7220 (1949).

Review of U. S. literature on corrosion of petroleum distilling and condensing equipment, and means for prevention.

8.4, 4.4

The Attack of Vanadium-Containing Oil Residues on Heat-Resistant Steels. (In German.) P. Schlapfer, P. Amgwerd and H. Preis. *Schweizer Archiv für Angewandte Wissenschaft und Technik.*, 15, 291-299 (1949) Oct.

Results of experiments at 650-850°C show that vanadium-containing fuel-oils greatly accelerate the scaling of heat-resistant steels if the temperature is above the melting point of the mineral residue, that the rate of attack increases with temperature, and that it is proportional to quantity of reacting material and to exposure time. Alkali in the residue also affects the rate of attack, but no attack occurs in a reducing atmosphere. Mechanism of attack is explained. Includes photographs, graphs, and tables.—BLR.

8.4, 7.4, 6.4

Experience with Condenser Tubes at a Major Oil Refinery. S. J. Van der Baan. *Corrosion*, 6, No. 1, 14-18 (1950) Jan.

Information collected at the Curacao Refinery of the CPIM is given. The performance of tubes of product and steam condensers is always under close supervision and the total number of Cu alloy tubes now in use is over 300,000. Corrosion by acidic condensate, impingement attack, and dezincification in product condensers, fatigue, corrosion fatigue, high temperature attack, hot spots and steam condensers are discussed. Al brass of good quality is a versatile and economical condenser tube material for the conditions prevailing at Curacao. Compliance with the usual specifications is not in itself a guarantee of adequate performance as corrosion resistance depends on other factors also which as yet are not known with certainty. Full length annealing to a hardness of ± 100 Brinell and the formation of an oxide skin are probably beneficial in this respect. A reasonable cheap and satisfactory alloy for water boxes to be used in connection with naval brass tube sheets is still sought for.—INCO.

8.4

Corrosion in Condensate and in High Pressure Sweet Oil Wells. R. C. Buchan, The Humble Oil and Refining Co. *Corrosion*, 6, No. 6, 178 (1950) June.

This article summarizes the present status of the serious corrosion problem in condensate and high pressure oil wells, and some of the mechanical and chemical aspects involved in alleviating the corrosion. Selection of tubing and well-head assembly materials, and means of reducing thread leakage are considered.

Data indicates that the most economical method of controlling condensate well corrosion is the injection of neutralizing agents, chromates, or organic wetting or emulsifying agents. Periodic injection of sodium silicate shows promising results.—NALCO.

8.4, 4.6

Corrosion in Salt Water Drilling. Lloyd A. Brudvig. *Drilling*, 11, 69-61 (1950) May.

Describes above with emphasis on use of liquid plastic anti-fouling coating made by Plastic Coating Corp., Houston, Tex., for protection of metal surfaces. Cuprous oxide is included in the formulation.—BLR.

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8.4, 5.7, 3.5

Corrosion on New Distillation Unit Processing Low Sulfur Crude. D. L. Burns. *Corrosion*, 6, No. 6, 169-177 (1950) June.

Deals principally with the nature of corrosion in the furnace tubes, factors involved, and remedial measures used. Crude charged averaged 0.20% sulfur content. Ammonia injection was used in neutralizing corrosive elements in the atmospheric-tower overhead steam and alloy steel tubes were substituted for carbon steel in the radiant section of the furnace. Corrosion rates for the carbon-steel heater tubes are plotted vs. temperature and compared to those experienced when processing crude containing 1.5% sulfur. Discusses marked effects which tube wall temperatures have on the corrosion rates. 10 ref.—BLR.

8.4, 3.5, 6.2

Metals for High Pressure Hydrogenation Plants. G. A. Nelson, Shell Dev. Co., Paper, A.S.M.E. Meet. St. Louis, June, 1950. *Abstr. Mech. Eng.*, 72, 746-7 (1950) Sept.

Petroleum industry high pressure hydrogenation processes (hydrodesulfurization of oils, Fischer synthesis, destructive hydrogenation of oil residues or coal) operate at high temperatures and pressure where ordinary steels have their limits for safe operation. Although high alloy steels can be used, cheaper low-alloy steels are sometimes satisfactory. Tests and data from operating plants from which it is possible to establish practical operating limits for carbon and alloy steels for all degrees of service severity are summarized. Corrosive effects of sulfur, nitrogen, and carbon monoxide are considered. Hydrogen damage to the structure of carbon steels requires both high pressures and temperatures. Resistance of the carbon steels to hydrogen damage, which varies with the method of steel manufacture, is improved by including small amounts of carbide stabilizing elements in the steel. When corrosives other than hydrogen are also present, additional protective measures should be taken.

• Group V

8.5

Some Aspects of Cottrell Precipitator Operation in The Kraft Industry. C. E. Hand (Bloedel, Stewart & Welch, Ltd.). Paper before Canadian Pulp & Paper Assn., Pacific Coast Branch Tech. Sec., and Am. Pulp & Paper Mill Superintendents Assn., Inc., Pacific Coast Div., Joint Spring Conf., 1949. *Paper Trade J.*, 129, No. 19, 35-37 (1949) Nov. 10.

A summary of experience and conclusions so far arrived at in the operation and maintenance of one of the most recent Cottrell precipitator installations in the West. Corrosion is the principal cause of deterioration and failure of rods. A corrosive mixture of NaCl and SO₂ left in curtains and treaters is probably the cause. Closing the inlet dampers and diverting the vapors up the short stack does not help because the dampers soon become inoperative. Abandonment of louver principle of inlet damper and installation of a sliding gate type may solve the trouble. Air leaks cause corrosion in gas ducts and shell of precipitator. Draft in the treaters regulated by means of outlet damper to create a slight vacuum reduces effect of such leaks.—INCO.

ulated by means of outlet damper to create a slight vacuum reduces effect of such leaks.—INCO.

8.5, 7.6

Operational Difficulties Encountered in Kraft Recovery Unit at Pacific Mill, Ltd. M. E. Patterson. Paper before Canadian Pulp & Paper Assn., Pacific Coast Branch Tech. Sec., & Am. Pulp & Paper Mill Superintendents Assn., Inc., Pacific Coast Div., Joint Spring Conf., 1949. *Paper Tr. J.*, 129, No. 18, 33-35 (1949) Nov. 3.

Precipitator corrosion is due to the combination of high moisture content in the gases, NaCl, SO₂, and air leak in the unit. Protective spray coatings, use of Heresite and heating of insulator housings are all being considered. Suggested materials of construction are Monel, Inconel, and 18-8 stainless steel. Monel is not regarded favorably due to moist SO₂ and H₂S gases present in any sulfate system. NaCl has a pitting tendency with both Inconel and 18-8 stainless, but the latter two are more desirable.—INCO.

8.5

Corrosion Problems in the Pulp and Paper Industry. R. P. Whitney. Paper before NACE, 5th Ann. Conf., Cincinnati, April 11-14, 1949. *Corrosion*, 5, No. 12, 435-439 (1949) Dec.

A number of corrosion problems encountered in the pulp and paper industry are reviewed and discussed. Several of the problems covered are common to many paper mills. Such problems are associated with pulp bleaching, cooking liquor recovery, liquor recovery, paper stock and white waters and various pieces of equipment. Uses and behavior of ferrous and non-ferrous metals and alloys are discussed.—INCO.

8.5

Kraft Papermaking. F. G. Sawyer, C. T. Beals, A. W. Neubauer. *Ind. Eng. Chem.*, 42, No. 6, 1007-1020 (1950) June.

The screens to separate the kraft pulp from the shives are made of chromium-plated bronze. Pulp beaters are steel fly bars fitted onto a heavy iron roll. Monel cutting bars are used in the Jordan refiner. Flowsheets. 41 references.—INCO.

8.5

Kraft Pulp Production. F. G. Sawyer, W. F. Holzer, L. D. McGlothlin. *Ind. Eng. Chem.*, 42, No. 5, 756-767 (1950) May.

The digestors are made of high silicon steel for better corrosion resistance. Stainless steel shells are used as liners in some of the digestors. The life of ordinary boiler plate is 10 years with a corrosion penetration of 1/16 in. per year. Unlined silicon steel lasts for 12 years. The blow tank is made of 3/8-inch mild steel plates. Flowsheets. 12 references.—INCO.

8.5

New Sulphite Bleachery at E. B. Eddy Company. Canada. *Paper Ind.*, 32, No. 2, 156-160 (1950) May.

One of the chlorinators in the sulfite bleachery is made of chromium-nickel steel and is rubber covered. The caustic tower is made of tile-lined steel. All the stock pumps and the white water pumps are Niresist, except the chlorinated stock pump which is rubber-lined steel. The piping in the screen and wet machine rooms are welded steel pipe, Lithcoted inside and out. The headboxes, flowboxes and stock spoutings are made of

fabricated steel, Lithcoted inside and out. The screens are stainless steel plates, as are the instrument control panels throughout the plant. Stainless steel exhaust ducts are used in the ventilating system. Caustic solution storage tanks are made of steel. Flowsheets.—INCO.

• Group VI

8.6

Welding Eliminates Corrosion in a Commercial Laundry Washer. F. A. Gerlach. Paper for J. F. Lincoln Arc Welding Foundation Contest. *Elec. Mfg.*, 41, No. 5, 122-123 (1948) May.

The use of arc welding in construction of all-Monel commercial laundry is described. Monel was used for its corrosion resistance.—INCO.

8.6, 5.4

Coating for Bale Ties to Be Tested by Mills. *Textile Ind.*, 112, 85 (1948) Nov.; *Text. Tech. Dig.*, 6, 77 (1949); *NPVL Abs.*, 1949, No. 145, 78.

A colorless rust-protective coating that will withstand high temperatures, dries quickly, and has a low viscosity is being tested by spinning mills for steel cotton bale ties. It is claimed that the coating will not rub off into the bale.—RPI.

8.6, 4.3

Chlorite Applications in the Textile Industry and the Effects of Chlorites on Metallic Equipment. J. Meybeck. *Teintex*, 14, No. 12, 505-519 (1949).

The conditions most suitable for the employment of chlorite solutions in the textile industry are also those most conducive to attack of the equipment used. After giving an outline of the chemistry of the chlorites, Meybeck briefly reviews previous work on their effects on metals, and reports a laboratory study of the corrosion resistance of a range of ferrous and non-ferrous metals and alloys exposed to sodium chlorite liquors (5 g/l., pH 4, 80° C., duration of exposure 7-10 days). Extremely good corrosion-resistance was observed in the case of passivated molybdenum-containing stainless steels of the 18:8 type. The solution-decomposing action of nickel and of nickel-base alloys was notable feature, leading to the conclusion that these materials would not only be attacked during textile bleaching, but would affect the bleaching process. Coating of metals with corrosion-resistant substances has not appeared to be completely successful, but all such substances have not yet been tried. The solution of the problem lies in a passivation treatment or cathodic polarization.—MA.

• Group VIII

8.8, 5.3

Corrosion Prevention in the Plating Shop. *Electroplating*, 3, No. 4, 135 (1949) Dec.

Nutracote is a liquid plastic coating material composed of inert resins in a ketone solvent which can be applied by brush or spray to give a hard, flexible and lustrous surface with unusual chemical resistance. It does not oxidize and is non-inflammable when dry. It gives protection against fumes and splash from



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sulfuric, phosphoric, hydrochloric, nitric (up to 30%), chromic and hydrofluoric acids, and other corrosive salt solutions, alkalies, oils, and fats.—INCO.

8.8, 2.2, 6.5

Corrosion Tests in the Processing of Soap and Fatty Acids. W. Z. Friend and J. F. Mason, Jr. *Corrosion*, 5, 355-367; discussion, 367-368 (1949) Nov.

Summarizes results of tests made in operating equipment in soap and fatty acid plants during the past 10 years, using mostly the spool-type testing device. The program included nickel, Monel, Inconel, and other high nickel-alloys, stainless steels, copper and copper-alloys, aluminum, chemical lead, mild steel, alloy steels and plain and alloy cast irons. Test results are evaluated where possible.—BLR.

8.8

A Staff-Industry Collaborative Report-Chemicals from Fats. R. L. Kenyon, in Collab. with D. V. Stingly and H. P. Young, Armour & Company. *Ind. Eng. Chem.*, 42, No. 2, 202-213 (1950) Feb.

Type 316 stainless steel is used throughout the plant where there is contact with fatty acids. The exception to the rule is in the heater tubes where the temperature rises above 300° C. Corrosion of Type 316 increases substantially as the temperature rises, whereas Inconel maintains its resistance. Table shows results of laboratory studies on corrosion effects of tall oil on Types 316, 317 and 302 stainless, Inconel and Hastelloy C. Reduced Ni formate catalyst is added to fats in the hydrogenation vessels, and the catalyst used for the conversion of nitriles to amines is Raney Ni. Fatty acids for processing are stored in Type 347 stainless clad tanks and carried in pipes of the same material. Finished product fatty acids are stored in Al tanks. Some of the pumps handling fatty acid materials are of Durimet 20 stainless steel. In preparing high melting acids, a Cr-plated rotating drum picks up a thin film of the acid which solidifies. 36 references.—INCO.

8.8

Highlights in Production of Melamine and Urea Resins. J. A. O'Connor. *Chem. Eng.*, 56, No. 12, 88-91; Flowsheet, 164-167 (1949) Dec.

Stainless steel centrifugals pump formaldehyde from tank car to storage. A stainless line carries the formaldehyde from storage into the stainless kettle. Liquid resin is pumped in a stainless line into a stainless steel mixer. Galvanized iron shells of dryers are coated with acid-resistant paint. Continuous belt in each dryer is Cd-plated. Spray-dried resins are made in stainless steel kettles.—INCO.

8.8

Armour's Star. R. H. Potts and G. W. McBride. *Chem. Eng.*, 57, No. 2, 124-127, Flowsheet, 172-175 (1950) Feb.

Armour & Co. has built a new plant at McCook, Ill., which will enable it to make a larger number of chemicals from fats, oils and fatty acids. Ni-Resist is used for the fatty acids pumps and ordinary steel for other stocks. The storage tanks for the fatty acids are stainless-clad steel. Monel-lined tanks are used for refining and bleaching of fat with H₂SO₄, and are used for storage of H₂SO₄ and 50% NaOH. Acetic acid is stored in stainless steel tanks. The evap-

orator is stainless steel. Type 316 steel is used for the bubble plate still of the fractional distillator. In the nitrile conversion stainless steel is used for the reactor, converter, reflux condenser, vapor superheater, pitch column, and all connecting pipes and valves where fatty acids are present. Ni is the catalyst used in the conversion. Ni formate is the catalyst in the fat and fatty acid hydrogenation. Finished products of fatty acids are kept in Al tanks, and the amines and nitriles are in steel tanks.—INCO.

8.8, 6.2, 6.4

The Salt Industry and Corrosion. Centre d'Information du Nickel. (In French.) *Rev. Nickel*, 15, No. 2, 21-28 (1949) April-May-June.

Processes of salt production; behavior of construction materials in various parts of the plant, in particular Monel and three types of Ni-Resist.—BNF.

8.8, 7.6

Armour Chemical Division Builds New Fatty Acid Plant. J. E. Bradbury. *Crane Valve World*, 47, No. 1, 21-25 (1950).

In the fat splitting process, evaporation of the sweet water from the splitter is accomplished in a stainless steel double-effect evaporator, the recovered crude glycerin being shipped to the refining plant. The still for distillation is a three column, high vacuum, bubble plate type fabricated of Type 316 stainless steel. Hydrogenation of the nitriles to make amines is carried out in high pressure autoclaves in the presence of a nickel catalyst.—INCO.

8.8, 3.7, 6.3

Copper and Copper Alloys for Chemical Plant. I. Boodson and E. Davis. *Soc. Chem. Ind., Conference on Materials of Construction in the Chemical Industry*, 153-159 (1950) Apr.

Copper, its properties and applications; effect of small amounts of alloying elements; alloys and their uses (Cu-Zn, Cu-Al, Cu-Si, Cu-Ni).—BNF.

8.8, 7.10, 6.5

New Crystal Ammonium Sulphate Plant at A.I.S. Kembla Works. B.H.P. *Rev.*, 27, No. 2, 20-22 (1950) Mar.

The metal sprays for the spraying of acidic ammonium sulfate solution at the ammonium sulfate plant of the Australian Iron & Steel Ltd. Kembla Works are made of Monel. The slurry feed hoppers are stainless steel. All pumps are made of Worthite, a Ni-Cr-Fe-Si-Mn alloy. This alloy is resistant to the abrasion of the sulfate and to the corrosion of the acid. Pipe lines are rubber lined. Valves in contact with the acid solution and the Eimco dryer's drum and screens are Monel.—INCO.

8.8, 5.1

Protective Materials in the Chemical Industry. P. Bourgois. *Revetement et Protect.*, 2, 123 (1949); *Chem. Abs.*, 44, No. 10, 4604i (1950).

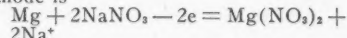
A review covering the corrosive agents, temp. limits of protective materials, nature and lifetime of installations, production capacities, physical and mechanical properties (tables of thermal conductivity and specific heats), and classified list of protective materials in three sub-divisions: minerals, metals, and organic materials.—RPI.

• Group IX

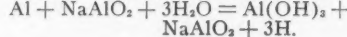
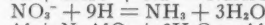
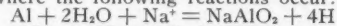
8.9, 6.4

Corrosion Problems Arising from the Use of Magnesium Alloys in Aeronautical Construction. L. F. LeBrocq and H. G. Cole. *Metaux et Corrosion*, 24, No. 289, 211-215 (1949).

LeB. and C. describe examples of and experiments on the serious corrosion of chromate-treated and painted magnesium alloys, which may occur in the presence of an electrolyte. 1) Rapid corrosion occurs when magnesium alloy is in contact with Duralumin in the presence of a certain de-frosting agent (sodium nitrate solution). Both the magnesium alloy and the Duralumin are attacked simultaneously, magnesium nitrate being formed at the magnesium anode and sodium aluminate at the aluminum cathode. Tests showed that the reaction at the anode is



The Na⁺ ions migrate to the cathode, where the following reactions occur:



Little trouble is experienced if a non-ionized de-frosting agent (e.g. glycol) is used. 2) Severe attack was found when magnesium alloy parts were stored in a poorly ventilated wooden case. Experiments showed that the corrosion was caused by acetic acid vapor emitted from the wood and by carbon dioxide formed by fungus growths on the paper wrapping. The trouble is minimized by good ventilation. 3) Magnesium alloy tanks containing wet leaded fuel are badly corroded where the water lodges. Protection is obtained by means of an inhibitor cartridge containing pure calcium chromate. 4) Corrosion of joints in welded assemblies, due to flux inclusions, can be prevented by washing, heating to 120° C, and painting immediately.—MA.

8.9, 1.7

Fatigue Tests of Rail Webs. R. S. Jensen. *Amer. Railway Eng. Assoc. Bull.*, 51, 640-647 (1950) Feb.

Consists of Appendix 11-b to Report of A.R.E.A. Committee 4 on Rail. Presents laboratory test data and their evaluation as a part of a continuing research program on the above. Includes corrosion-fatigue data in tap water of two types.—BLR.

8.9, 6.4

Light-Alloy in the Petroleum Industry. *Light Metals* (England), 12, No. 142, 633-640 (1949) Nov.

This account concluded the discussion on aluminum and magnesium for oil transport equipment and terminates with a section dealing with magnesium for cathodic protection.—ALL.

8.9, 5.4

Plastic Coated Tug for the Amazon. *Marine Eng. and Shipping Rev.*, 54, 54 (1949) Dec.

Because of the intense heat and the corrosive properties of the water at the mouth of the Amazon in South America, special precautions were taken in the construction of the 50-foot twin-screw Diesel tug Mooremack T-3 of the Moore-McCormack Lines. All exposed metal surfaces were sprayed with a plastic

coating designed to protect surfaces against fungus growth and corrosion. The crew's quarters were lined with 3-inch insulation and the engine room was designed with large lightweight steel hatches capable of being removed for increased ventilation. Each screw is driven by a 225 h.p. Diesel engine.—TIME.

8.9, 3.5

The Protection of the Pipelines of La Régie Autonome des Pétroles Against Electrolytic Corrosion. Y. Boyer. *Métallurgie et Corrosion*, 23, Nos. 271/272, 79-88 (1948).—MA.

8.9

Some Metallurgical Aspects of Automobile Manufacture. F. D. Brookshire. *Australasian Eng.*, 1949, 69-73, May.

The common metals, alloys, and metallurgical processes used in the manufacture of passenger automobiles in the U.S.A. are described. Non-ferrous metals comprise 3% by weight of an average American automobile, and the following are the more important of their uses. Aluminum alloy pistons are usually made of the following alloy: 12% silicon, 2½% nickel, 1% magnesium, 1% copper, remainder aluminum, and cast in permanent moulds. The pistons are anodized in a sulfuric acid bath to provide a hard, wear-resistant skin (0.0003 in. thick). The upper and lower tanks in the radiator are 67:33 deep-drawing brass, and the tubes or fins are copper. Tin-lead solder is used for joining. Bronze bearings used in the gears may be any one of several types; a common material is bronze strip of the following composition: 4% tin, 4% lead, 2.75% zinc, remainder copper. Bronze bushings are commonly used for the kingpins. Typical compositions are: 25% lead, remainder copper (used with a steel back), and wrought bronze, 4% tin, 4% lead, 2.75% zinc, remainder copper. Door handles are usually zinc-base die-castings, copper-nickel-chromium plated 0.001-0.0015 in. thick. The alloy commonly used contains: 4% aluminum, 1% copper, remainder zinc. Exterior body hardware should withstand at least 48 hours' salt-spray test. Plated parts, where corrosion-resistance is desired and appearance is not important, are usually zinc-plated, often followed by a chromate treatment. Cadmium plating is also used, but is more expensive. The plating thickness is about 0.0003 in. on such parts.—MA.

8.9, 5.8

Use of Ammonia in Control of Vapor-Zone Corrosion in Storage Tanks. F. T. Gardner, A. T. Clothier, Carter Oil Co., and F. Coryell, Interstate Oil Pipe Line Co. Paper before API, Ann. Mtg., Chicago, Nov. 7, 1949. *Oil & Gas J.*, 47, No. 27, 238+ (1949) Nov. 10. *Abst. Petro. Eng.*, 21, No. 12, D 18+ (1949) Nov. *Abst. Corrosion*, 6, 58-65 (1950) Feb.

Preliminary, but extensive laboratory study showed that H_2S corrosion could be retarded by NH_3 in a concentration of 1/10th of that necessary to neutralize the sour gas. Initial field studies in lease tanks, utilizing ammonium carbonate as a source of NH_3 , were encouraging, but not conclusive. Testing was extended to pipe-line storage tanks using anhydrous NH_3 and the degree of protection obtained was very high. Use of anhydrous NH_3 proved to be an economical method of quickly achieving protection of the vapor zone.—INCO.

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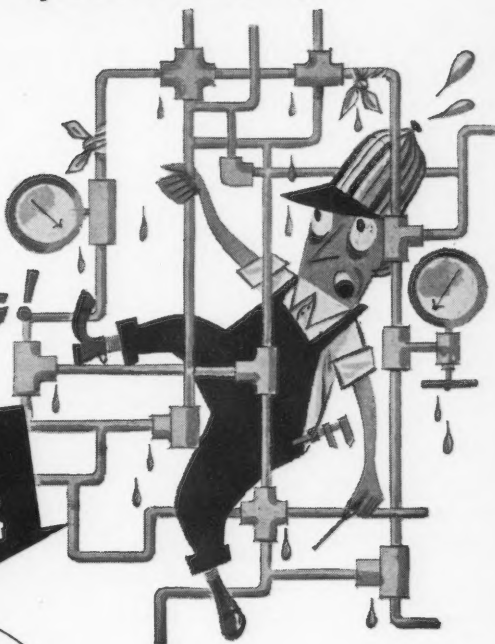
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8.9 **Basic Problems in the Engineering of a Modern All-Metal Motor Body.** E. S. White. *IME Proc.* (Automobile Div.), Part I, 1948-49, 10-15.

Discusses above from the British viewpoint. The range of materials (steels and Al alloys) from which a body may be made is described in some detail. The relative merits of different forms of construction are examined in the light of quantity production. An example is given of the way in which multiple pressing operations can be facilitated by careful sequence planning. A section on corrosion prevention is included.—BLR.

8.9 **Cold Starting and Cylinder Wear. Corrosion to Blame for the Missing "Thous"?** H. H. Stuart. *Autocar*, 94, 77 (1949) Jan. 28.

Brief summary of some conclusions drawn from research carried out some years ago by Institution of Automobile Eng., followed by discussion of factors affecting wear. Cylinder wear appears to be caused by corrosive attack rather than by wear, as generally understood. Importance of cylinder-wall lubrication is stressed and methods which may be adopted to minimize wear are listed.—INCO.

8.9, 6.4 **Causes of Corrosion in Aeroplanes and Methods of Prevention.** N. H. Simpson. *Corrosion*, 6, No. 2, 51-57 (1950) Feb.

Various types of corrosion which may occur on present types of aircraft and the latest methods of combating them are described. Demands for speed and range in modern aircraft have increased the search for stronger metals until now the design ultimates are nearly doubled. Increase in strength has been obtained by development of new alloys or by strengthening the material by process changes. Low density magnesium alloys are used for castings, a large number of skins and other parts of aircraft. The magnesium has greater stiffness per unit weight as a rod is four times as stiff as an aluminum

one of equal size. Thinner sections were used as the strength of the metals increased, presenting tougher corrosion problems. Dissimilar metal assemblies which are very common in aircraft parts are seriously afflicted by galvanic corrosion. Test results showed that magnesium alloys, steels and bare manganese bronze must be well insulated from 75ST aluminum when used in dissimilar metal contacts. If halogens are present galvanic corrosion will continue unabated until the aluminum alloy is destroyed. As the speed of aircraft is increased, higher pressures cause gases such as oxygen, ozone, water, nitrogen, sulfur dioxide, carbon dioxide, etc., to be forced into closer contact with the metals. Corrosion rate is increased by changing the equilibrium constants of the chemical film already formed on the metal under normal conditions. The temperature of the metal in the air stream also is increased and in general heat tends to promote corrosion. Organic coatings which formerly were able to protect metals have not been developed to withstand the heat, water and abrasion of high speeds. Corrosion engineers must develop methods of protecting metal from all types of atmospheres. Increasing energy of vibration is powerful enough to cause metal fatigue. High frequency, high voltage ac electricity induces eddy currents which produce a corrosion problem in that stray currents will promote both anodic and cathodic corrosion.

Tables give the following information: 1) design properties of the most important alloys used in aircraft; 2) variety of environments to which aircraft are subjected; 3) effect of different electrolytes on the solution potentials of metals; 4) corrosion effect of various bubble fluids on clad 24ST aluminum and F5-lh magnesium alloys; 5- general finish requirements for an aeroplane.

The methods used by Convair to minimize corrosion on its planes by design, new means of joining methods, and prevention of shop troubles are listed and described.—ALL.

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8.9, 7.5, 5.4

Developments in Corrosion Prevention in West Texas. H. D. Murray and W. H. Crenshaw. *Oil Gas J.*, 48, No. 51, 166-168 (1950) April 27.

Lease-bottom steel tanks that have deteriorated to a state that normally would require replacement, can be repaired by the use of a thermosetting plastic and an inert filler. The film is $\frac{3}{8}$ -inch thick over the entire bottom of the tank plus a coating extending at least 12 inches up the sides. Sumps on cone-bottom tanks are made of ordinary or corrosion resistant steel, and aluminum rods and tubes are being tested for corrosion resistance, but the results are not conclusive although some success has been achieved. Plastic or concrete coatings are being used in pipe lines and are applied in situ. Corrosion attack on the unengaged threads of the drill-collar joint may be the cause of numerous fatigue cracks in the threads.—INCO.

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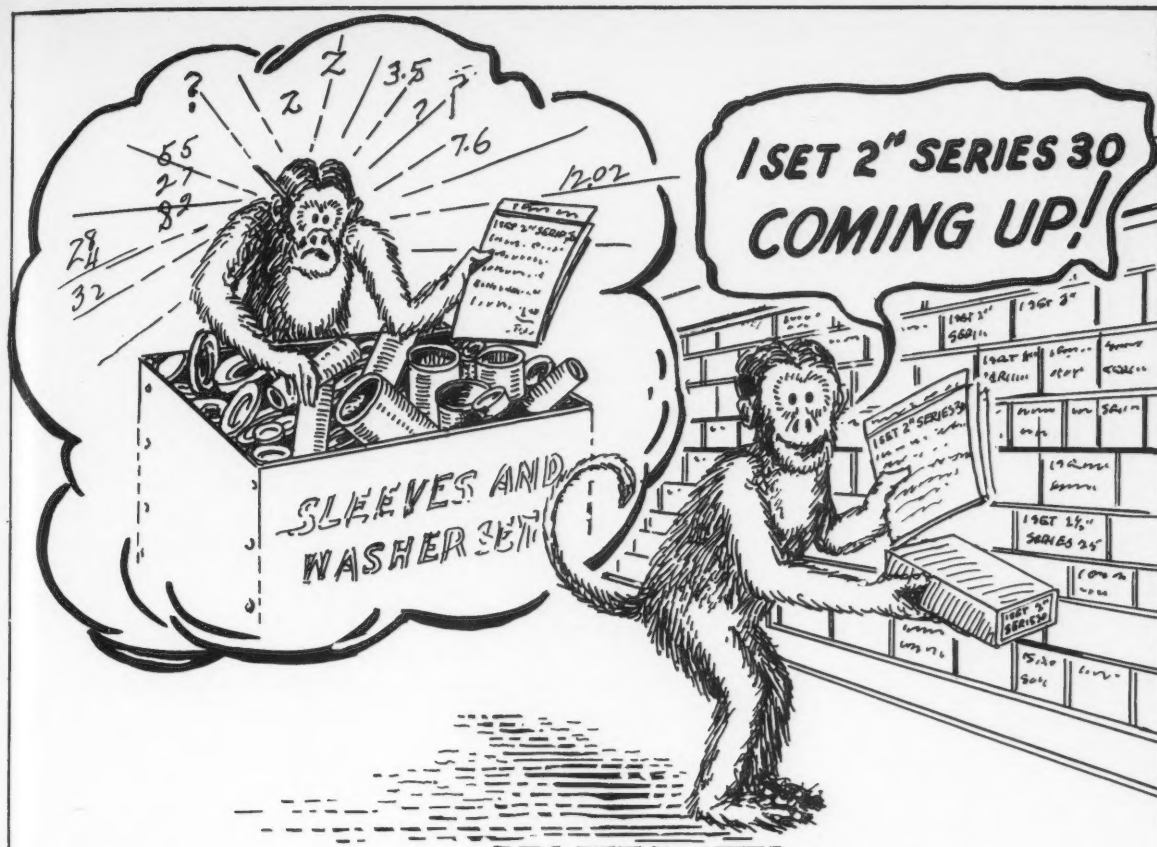
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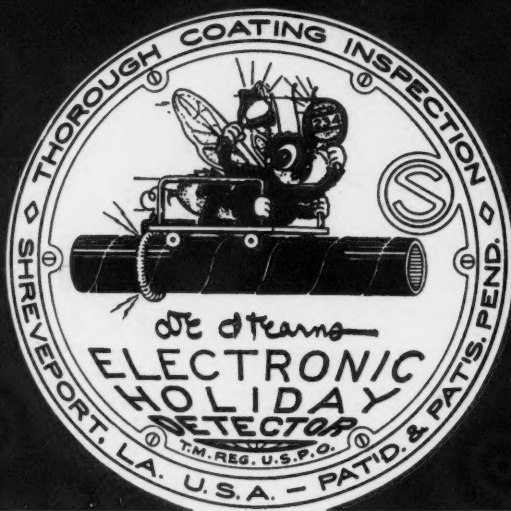
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